epiSTEME - 9

International conference to review research on Science, Technology and Mathematics Education

Proceedings

Homi Bhabha Centre for Science Education, TIFR
Mumbai, India
July 4—8, 2022

Editors
Deepa Chari (she/her)
Ayush Gupta (they/them)

PROCEEDINGS OF

EPISTEME 9

International Conference to Review Research
in Science, Technology and Mathematics Education
July 4—8, 2022
https://episteme9.hbcse.tifr.res.in/

EDITORS

Deepa Chari (she/her)
Ayush Gupta (they/them)

Homi Bhabha Centre for Science Education
Tata Institute of Fundamental Research
Mumbai, India

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PREFACE

Conference epiSTEME is a biennial international event to review research in science, technology, engineering, and mathematics (STEM) education hosted by Homi Bhabha Centre for Science Education (HBCSE), a National Centre of Tata Institute of Fundamental Research (TIFR). The first epiSTEME was held in 2004, and since then eight epiSTEME conferences have been organised. Research on STEM education is a growing area in India. The epiSTEME conferences have provided a venue for researchers from around the world to network, share knowledge, grow in their scholarship, and have strengthened efforts for transformation of STEM teaching and learning. Details of the past eight editions of the conference is available at http://www.hbcse.tifr.res.in/episteme

The ninth edition of epiSTEME is being held during difficult times in India and around the world. It is hard to capture the pain, grief, and uncertainty that the COVID-19 pandemic has thrown us in. We hope that during the conference we can come together, albeit virtually, to spend some time in community, to share, both personally and professionally. epiSTEME 9 will take as its focus two intertwined issues emerging arguably as the "grand challenges" within STEM education worldwide: (i) how do we conceptualise equity and address inequality of access and opportunity in STEM for learners from marginalised backgrounds and (ii) how do we translate what has been learned through research into educational practices towards transforming STEM education. epiSTEME 9 will deepen understanding on these issues through generating vigorous dialogue between and amongst national and international scholars in science, technology, and mathematics education.

Broadly, the conference is organised under 4 strands:

Strand 1. History/Philosophy/Ethics of STEM- implication for education

- Theme 1: History and Philosophy of STEM
- Theme 2: Socioscientific Issues and STEM Ethics
- Theme 3: Policy and STEM Education
- Theme 4: Equity, Access, and history/philosophy of Disciplinary Practices

Strand 2. Cognitive and affective studies of STEM

- Theme 1: Disciplinary practices in STEM
- Theme 2: Disciplinary knowledge and epistemologies in STEM
- Theme 3: Affective aspects of learning and teaching
- Theme 4: Identity, agency, and belonging in STEM

Strand 3. Pedagogy, Curriculum and local context in STEM

- Theme 1: School curriculum and pedagogy
- Theme 2: New Media and digital technologies in teaching and learning
- Theme 3: Equity and classroom interaction and discourse
- Theme 4: Assessment and evaluation

Strand 4. Research to practice in disciplinary and interdisciplinary spaces

- Theme1: Educational initiatives and innovations in discipline based education research
- Theme 2: Creating spaces for interdisciplinary learning and communication
- Theme 3: Innovations and Practical Dimensions of Teacher Professional Development
- Theme 4: Epistemological, social, and ethical responsibilities of student-teacher communities.

While the fourth strand targets the research to practice focus, 'equity' is included as a focused theme within every single strand. Besides these foci, the conference will also allow researchers to share knowledge and generate discussions on many ongoing lines of inquiry within STEM Education, pertaining to history and philosophy of the disciplines, sociocultural practices, cognitive and affective aspects of learning, and studies on curriculum and pedagogy.

The conference will feature 7 plenary talks by leading scholars in STEM education and learning sciences from 7 different countries. We also feature a workshop on intersectionality by two leading feminist science scholars in India. We received 51 submissions for the conference, from scholars in Burundi, Canada, Chile, India, Ghana, Nepal, Rwanda, South Africa, Switzerland, United States of America, and Zambia. Each manuscript was sent for review to 2-3 reviewers for double-masked review. A small team from HBCSE (consisting of PhD research scholars, faculty, and scientific officers) helped us to identify the reviewers. Based on the review process, we selected 23 papers for oral presentation, and 21 for poster presentation, and rejected 5 papers. 2 authors withdrew their papers. We encouraged discussion, reviews, and in-progress papers, including many such submissions as posters. We are hoping to provide a forum for authors to have extended interactions with the community through the epiSTEME9 platform. There are more spin-off events planned for extended interactions throughout the year.

We are grateful to the HBCSE community for help at various conference organising tasks. We thank Adithi Muralidhar, Anisha Malhotra-Dalvi, Arul Gansesh S S, Aswathy Raveendran, Charudatta Navare, Chaitanya Ursekar, Harita Raval, Reema Mani, and Shewta Naik for help with the review assignment process. We thank Panchami Jose, Joseph Salve, and Chaitanya Ursekar for getting the final manuscripts into a publishable format and coordinating the proceedings publication process. We thank Manoj Nair for designing the conference advertising poster, the website, helping with the registration process, and for general technical troubleshooting whenever needed. We thank Anil Kumar Sankhwar and Ashish Kumar Singh in the computer lab for helping with the virtual platform for the conference. Alka Bhoir helped with many different aspects of the program/schedule design, and many other last minute organisational tasks. We also thank Devendra Mhapsekar for his help during the registration process. We thank V. P Raul and Pragati Dandekar for help with the conference budget and official approvals. We thank Mashood K.K. and past epiSTEME convenors for sharing lessons learnt and procedures from organising the last epiSTEME. We also thank members of the Academic Committee for advice and encouragement and the Local Organising Committee (https://episteme9.hbcse.tifr.res.in/committees/) for help in various aspects of the conference.

Deepa Chari (she/her)

Ayush Gupta (they/them)

Co-Convenors, epiSTEME9

https://episteme9.hbcse.tifr.res.in

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STRAND 2: COGNITIVE AND AFFECTIVE STUDIES IN STEM EDUCATION

STRAND 4: RESEARCH TO PRACTICE IN DISCIPLINARY AND INTERDISCIPLINARY SPACES

SCHEDULE

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10.00AM—10.30AM	Welcome by Centre Director, HBCSE About epiSTEME 9: Our philosophy *Arnab Bhattacharya, Ayush Gupta & Deepa Chari*
10.30AM—11.30AM	Plenary talk 1: Sara Tolbert Title: Science education as a social movement *Chair: Aswathy Raveendran*
11.30AM—11.45AM	Break (15 minutes)
11.45AM— 01.30PM	Oral Presentation Session: Strand 4 Research to practice in disciplinary and interdisciplinary spaces *Chair: Anisha Malhotra-Dalvi*
11.45AM—12.00NOON	A model for the integration of pedagogic content knowledge in teacher training programmes *Serah Suman Potharay & Umakanth Dammalapati*
12.00NOON—12.15PM	Enriching micro-teaching skills with tspck framework in pre-service teacher education *Narendra Deshmukh & Eunice Nyamupangedengu*
12.15PM—12.30PM	Teachers' knowledge of students' thinking inferred from lesson plans in lesson study *Shikha Takker, Lisnet Mwadzaangati, Jill Adler & Craig Pournara*
12.30PM—12.45PM	Numeric equations: a key step in solving the equation problem *Craig Pournara & Shikha Takker*
12.45PM—01.00PM	Steam education for school teachers in Nepal *Indra Mani Shrestha, Bal Chandra Luitel, Binod Parsad Pant, Niroj Dahal & Netra Kumar Manadhar*
01.00PM—01.15PM	Effectiveness of Experiential Learning for the Topic of Length Measurements in Grade 6 *Anusha Bhat & Prathik Cherian J*
01.15PM—01.30PM	Closing Remarks by Chair
	Break (2.30 hours)
04.15PM—05.40PM	Workshop by Prajval Shastri & Chayanika Shah Title: Intersectionality *Moderator: Deepika Bansal*
05.40PM—05.45PM	Break (5 minutes)
05.45PM—06.45PM	Plenary talk 2: Heba El-Deghaidy Title: STE2AM and Social Responsibility in Higher Education *Chair: Aniket Sule*
06.45PM—06.50PM	Closing Remarks by Chair

Day 2: Tuesday, 5 July 2022	
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10.15AM—10.30AM	The possible missing ingredients in engineering higher education – mastering self, agency to shift disempowering norms and socialization and mastering technical skills *Arun Arul Selvam, Sri Bhavani Arul, Narmadha Anandavelu, Santhosh Kathiresan, Sivaraman Ramamoorthy & Sanjeev Ranganathan*
10.30AM—10.45AM	Biology Teachers' Planned Pedagogical Content Knowledge in Respiration: A case of a Zambian Secondary School *Thumah Mapulanga, Gilbert Nshogoza & Yaw Ameyaw*
10.45AM—11.00AM	Exploring status of science education in Indian rural classroom: a study of eastern districts of uttar pradesh *Kajal & Sunita Singh*
11.00AM—11.15AM	Classroom challenges before schools in the tribal regions *Asmita Redij & Aniket Sule*
11.15AM—11.30AM	Understanding the process of memetic reasoning in graduate students during Covid-19 - if you know what we meme! *Anveshna Srivastava & Chandan Dasgupta*
11.30AM—11.40AM	Closing Remarks by Chair
	Break (20 minutes)
12.00NOON—01.00PM	Plenary talk 3: Tan Aik Ling Title: Accessibility of STEM for teachers: What is at stake? *Chair:Mashood KK*
	Break (3 hours)
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04.00PM—04.10PM	Examining the effects of teachers' self-efficacy in teaching astrophysics using video-based multimedia *Gabriel Janvier Tugirinshuti, Leon Rugema Mugabo & Alexis Banuza*
04.10PM—04.20PM	Study of damped oscillatory motion of spring-mass system using video analysis technique *Rajesh Bm, Shubha S, Avadhani Dn, Satish Bm & Madhura Tk.*
04.20PM—04.30PM	Learning With Algodoo: Simulation Building as a Pedagogic Tool *Prathik Cherian J*
04.30PM—04.40PM	Intergation of steam in chemistry classroom *Puneeta Malhotra*
04.40PM—04.50PM	Mathematics for All and Everyone's Mathematics *Pradnya Kadam*

04.50PM—05.00PM	Game-based learning to raise awareness about water sustainability *Parth Dhond & Anisha Malhotra-Dalvi*
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06.45PM—06.50PM	Closing Remarks by Chair

	Day 3: Wednesday, 6 July 2022
	No morning/afternoon sessions
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05.30PM—05.45PM	A call for mobilizing mathematics education towards gender equality in India Mahati Kopparla
05.45PM—06.00PM	The nature of steam education curriculum in Nepal *Netra Kumar Manandhar, Bal Chandra Luitel, Binod Prasad Pant, Indra Mani Shrestha & Niroj Dahal*
06.00PM—06.15PM	Developing Informal Inferential Reasoning: Evidence from Tribal Area of Palghar District *Mitali Thatte & Nilesh Nimkar*
06.15.PM—06.30PM	Exploring the scope for using data science in the teaching and learning of mathematics: an action research among secondary school students *Jasneet Kaur*
06.30PM—06.45PM	Affective draw: gamified mathematics activities for improved maths learning, attitudes, and interdisciplinary transfer *Amèya Kolārkar*
06.45PM—07.00PM	Use of analogies for class 6 students to classify plants: verbal analogies versus activity-based analogies *Kruthika Bs & Pratistha Agarwal*
07.00PM—07.10PM	Closing Remarks by Chair
	Break (20 minutes)
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Day 4: Thursday, 7 July 2022	
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10.00AM—10.15AM	Artistic ways of knowing reinforcing interdisciplinary science learning *Dave Del Gobbo, Sheliza Ibrahim, Sarah El Halwany, Majd Zouda, Nurul Hassan, Mirjan Krstovic, Larry Bencze, Gonzalo Guerrero & Nicole Kofman*
10.15AM—10.30AM	Regional disparities in educational opportunities in Kerala *Muhammed Kutty P V, Ahmed Ashraf Z A, Fajrul Ihsan P V & Hashim N K*
10.30.AM—10.45AM	Towards an evidence informed policy-making model: design and implementation of a teacher professional development program *Arjun Prasad, Sanjay Chandrasekharan, Sreejith Alathur & K K Mashood*
10.45AM—11.00AM	The vulgar and the pristine: exploring the barriers in using the vernacular while talking about sexuality in biology classrooms. *Panchami Jose*
11.00AM—11.15AM	Promoting critical mathematical literacy *Nadia Kennedy*
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11.40AM—11.50AM	Climate Change in Environmental education in Middle-schools over West Bengal: status and perception evaluation *Arindam Roy*
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12.00NOON—12.10PM	Experiencing covid-19 pandemic from the lens of realistic mathematics education (RME) *Kumar Gandharv Mishra*
12.10PM—12.20PM	High school student's participation in scientific investigations: its impact on their competencies and attitude towards science *Venkata Krishna Bayineni*
12.20PM - 12.40PM	Q&A Closing Remarks by Chair
	Break (2 hours 50 minutes)
03.30PM—04.30PM	Plenary talk 6: Louise Archer Supporting Equity and Inclusion in STEM *Chair:Jayasree Subramanian*
	Break (1.30 hours)
06.00PM—07.20PM	Poster presentation session: Strand 3 Pedagogy, Curriculum and local context in STEM education *Chair:Charudatta Navre*

06.00PM—06.10PM	Teachers' belief and practices related to using stories as science pedagogy *Punam Medh & Shamin Padalkar*
06.10PM—06.20PM	Identifying gaps in students' understanding of algebraic identities: Tools from Indic Knowledge Systems *Vinay Nair*
06.20PM—06.30PM	Anandi: using print media to reach the unreached during the pandemic and beyond *Asmita Redij, Arnab Bhattacharya, Megha Chougule, Vikrant Ghanekar, Suravi Kalita, Sarita Kamat, Vijay Lale, Shweta Naik, Vikram Patil, Harita Raval, Pritesh Ranadive, Uzma Shaikh, Sai Shetye & Aniket Sule*
06.30PM—06.40PM	An exploration of professional noticing and PCK (Pedagogical Content Knowledge) among teacher educators from low resource countries *Anirudh Agarwal, Arushi Bansal & Ruchi Kumar*
06.40PM—06.50PM	Fluency in single-digit addition and related subtraction facts among indian students *Praveena Katragadda & Maulik Shah*
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Day 5: Friday, 8 July 2022

10.00AM—11.00AM	Plenary talk 7: Senthil Babu Title: Mathematical Experience and Alienation: Towards social histories of Practice *Chair: Shweta Naik*
	Break (20 minutes)
11.20AM—12.30PM	Poster presentation session: Strand 1, 2, 3 & 4 (mixed) History/Philosophy/Ethics of STEM – implication for education, Cognitive and affective studies of STEM education, Pedagogy, Curriculum and local context in STEM education & Research to practice in disciplinary and interdisciplinary spaces. *Chair:Sarita Kamat*
11.20AM—11.30AM	Integration of public health and proportional reasoning-a demand of time *Debasmita Basu*
11.30AM—11.40AM	Experiential learning in school mathematics: transforming theory into practice *Tarun Tyagi*
11.40AM—11.50AM	A preliminary study: beating the barrier of language in science teaching for underprivileged students *Anamika Sharma, Subhadip Senapati & Athavan Alias Anand*
11.50AM—12.00NOON	Socioscientific Issues and Science Education *Vishal Kumar & Sanjiv Kumar Choudhary*

12.00NOON—12.10PM	Mereology For STEAM and Education Research *Mani A*
12.10PM—12.30PM	Q&A Closing Remarks by Chair
12.30PM—01.00 PM	Feedback & concluding remarks by epiSTEME 9 Convenors *Deepa Chari, Ayush Gupta, and epiSTEME 9 participants*

REVIEW TALKS

SUPPORTING EQUITY AND INCLUSION IN STEM

Louise Archer

University College London, UK

What causes inequalities in STEM participation and why are these so resistant to change? What can be done to make STEM participation more equitable and inclusive? In this talk I draw on findings and resources from several large research studies, including insights from the 13 year ASPIRES longitudinal study (which tracked a cohort of young people from age 10-23 to identify factors shaping STEM trajectories) and resources and teaching approaches developed by the Youth Equity +STEM project and the Primary Science Capital Teaching Approach project, both of which involved co-designed tools for practitioners to support equitable and inclusive practice.

Louise is the Karl Mannheim Professor of Sociology of Education at UCL (UK). Her research focuses on educational identities and inequalities, particularly in relation to participation in STEM, across primary, secondary and higher education and in informal STEM learning settings. She has directed numerous large research studies focused on understanding inequalities in STEM participation and has authored over 100 articles, books and chapters. She is particularly interested in co-design work with teachers and educational practitioners and was awarded prizes for the impact of her work in 2019 and 2020.

MATHEMATICAL EXPERIENCE AND ALIENATION: TOWARDS SOCIAL HISTORIES OF PRACTICE

Senthil Babu D

French Institute of Pondicherry, India

History of mathematics has informed mathematics education, mostly as pedagogic aids in classroom practices. In this talk, I would like to propose how social histories of mathematical practices can open up interesting ways to understand the processes involved in the making of mathematical experience, and how they become alienable. Such alienability, however, has to be situated in the making of values, studied through the real-world practices of working people, who engaged in activities that were mathematical, as part of their occupations and work, what we call practitioner's mathematics. Reconstructing the social histories of these practices could then inspire new ways of thinking in mathematics education. In this talk, I would like to explore such possibilities, through the discussion of specific historical cases. The relationship between the measuring rod, labour and land in medieval south India, debates about money and fair exchange in early modern Europe through the writings of Nicolas Copernicus, the collander and mnemonic tables which graded and made values of precious goods such as pearls in early modern south India, and the case of ranking creditworthiness as a way of measuring trust in contemporary microfinance industry and working women are the four cases for exploration. The sites of learning of mathematics, in our view could go beyond conventional classrooms to organized learning spaces of knowledge exchange such as women's self help groups, artisanal workshops, and groups of working women and trade union spaces.

Senthil Babu D., is a historian of mathematics based at the French Institute of Pondicherry, in south India, where he is involved in studies concerning Nature, Knowledge and Labour [https://ifpindia.org/research/social-sciences/knowledge]. He is coordinating a research programme in the Social History of Vernacular Mathematical Practices in Medieval South India in collaboration with Chair, History and Philosophy of Mathematics at ETH, Zurich. His book, Mathematics and Society: Numbers and Measures in early modern South India, will be published soon by Oxford Universtiy Press in 2022. He is a member of the editorial board of the series, Verum Factum: Studies in Political Epistemology [https://verumfactum.it/]. He is a member of the Politically Mathematics Collective in India [https://www.politicallymath.in/]

STE^{2}AM AND SOCIAL RESPONSIBILITY IN HIGHER EDUCATION

Heba El-Deghaidy

The American University in Cairo, Egypt

Today's complex problems, sometimes called wicked problems, are claimed to be a direct result of the Anthropocene. This talk presents contributions from graduate and undergraduate students enrolled in a course offered at a not-for-profit private higher education institution in Northern Africa, on education for sustainable development. Before presenting the findings and students' project, I will share some global and local challenges that countries are facing related to the 2030 SDGs and the role of education in trying to solve these challenges. While doing so, I will present the main aspects of the learning journey that student went through while enrolled in the course. There will also be reference to what is meant by social responsibility at both the university and individual levels, especially as higher educational institutions could instill a sense of responsibility in students as change agents. The theoretical framework that guides this paper is based on Giving Voice to Values (GVV), an innovative approach to values-driven leadership development (Gentile, 2010) and the sociocultural constructivist framework (Lave & Wenger, 1991). As students work on real life problems in their locality, concepts and skills from the various STEAM disciplines are brought to the forefront as a learning process. An acronym that integrates both education for sustainable development and STEAM education is presented by 'STE2AM' as a transdisciplinary approach for learning.

A long-term aim of this talk is to explore how universities, as social institutions, can contribute to human and social development as a means to understanding universities' social responsibility while aligning their values with societal expectations through educating future generations. Findings indicate that students' end of course projects could be used as opportunities to voice their values as they develop their responsibilities toward their local communities.

Gentile, M. (2010). Giving voice to values: How to speak your mind when you know what's right. New Haven and London: Yale University Press. Curriculum site: www. GivingVoiceToValues.org

Lave, J., & E. Wenger. (1991). Situated learning: Legitimate peripheral participation. Cambridge: Cambridge University Press.

Professor Heba EL-Deghaidy is currently chair of the Department of Educational Studies at the American University in Cairo. Her doctoral degree in science education is from the University of Birmingham, UK. EL-Deghaidy is leading the STEAM education initiative as an international approach to an interdisciplinary learning model. She developed, designed and presented the first Arabic MOOC in STEAM education in Arabic hosted by Edraak. EL-Deghaidy's research focuses on science teacher education, preservice and inservice. Her publications are in the areas of STEM/STEAM education, Education for Sustainable Development (ESD), using educational technology in teaching and learning. Her recent publication is a co-edited book titled ' STEM in Science Education and S in STEM: From Pedagogy to Learning'.

USING STEM TO CENTER COMMUNITY DESIRES

Aachey Susan Jurow

University of Colorado Boulder, USA

Around the world, we are facing immense challenges to organizing inclusive and equitable forms of living together. Using research and design to support justice projects is, in my view, a moral imperative. In this talk, I discuss the affordances of community-based participatory design projects and their implications for understanding the role STEM can play in advancing justice. I share examples from projects that my collaborators and I have developed to understand how people work together to improve the conditions of their lives – for example, in the social movement for food and economic justice in the U.S. Mountain West. While STEM has not been the focal point of this work, I discuss how it has been an important design tool for advancing consequential learning with communities. An aim of this talk is to invite critical discussion of the ethical, conceptual, and methodological implications of our decisions as to when and how to use STEM in our research with community partners.

A. Susan Jurow is currently a Professor of Learning Sciences & Human Development program at the University of Colorado, Boulder (U.S.A.), Associate Dean for Diversity, Equity, and Community Engagement, and co-Editor in Chief of the Journal of the Learning Sciences (2021-2024).

Susan's publications have focused on understanding what counts as consequential learning for people – in schools, in communities, and in institutions of higher education. She has studied mathematics learning in middle school classrooms, learning as part of progressive social movements for justice, and learning and "un-learning" related to organizing for equity in institutions of higher education. Across these diverse contexts, Susan and her remarkable collaborators have foregrounded people's capacity to organize new futures while simultaneously struggling against entrenched systems of oppression.

ACCESSIBILITY OF STEM FOR TEACHERS: WHAT IS AT STAKE?

Tan Aik Ling

National Institute of Education, Singapore

STEM education has been a much-researched area of interest in the last decade. The issues related to educational accessibility and policies in STEM education has also gained traction in recent years. While societies worked on increasing accessibility of STEM learning opportunities for students, there is comparatively less attention paid to accessibility of STEM professional development opportunities for teachers. In this plenary talk, I delve into the need for strong STEM leadership in schools so that we can build STEM teachers' agency, identity, and a sense of belonging to a community. These three aspects are fundamental to meaningful planning, enactment, and sustainability of STEM programs in schools since research has pointed out that teachers' beliefs and intentions often influence their actions in their practices. I will also share programmes that have been implemented in Singapore to increase accessibility to STEM teachers' professional development and to build a sustainable STEM ecosystem through partnerships between schools-tertiary institutions-industries.

Tan Aik-Ling is an Associate Professor and Deputy Head (Teaching & Curriculum Matters) at the Natural Sciences and Science Education (Academic Group), National Institute of Education (NIE), Singapore. She is also a core team member with the Multi-centric Education, Research and Industry STEM Centre at NIE (meriSTEM@NIE). Her research focuses on the scholarship of science teaching and learning, science teacher professional development and STEM education.

WHO'S THE NEGATIONIST NOW? A DECOLONIAL PERSPECTIVE TO THE POST-TRUTH DEBATE IN STEM EDUCATION

Katemari Rosa

Federal University of Bahia, Brazil

In this presentation, I discuss post-truth, negationism, coloniality, and how they relate to science. I will argue that science and STEM education, guided by a white scientific logic that denies knowledge produced by Black bodies, position themselves in this negationist discussion of otherness. I will show examples of knowledge taken as objective facts that are, in reality, produced facts created by a racist community. These manufactured facts continue to be reproduced in STEM education, contributing to perpetuating racism in our society and in our research practices.

Katemari Rosa is a professor at the Institute of Physics at the Federal University of Bahia, where she is the local Physics coordinator of a Federal Teacher Education Program (PIBID), in Brazil. Her interests involve research and practice in physics teaching and additive manufacturing. Dr. Rosa grounds her work on feminist perspectives, Critical Race Theory, and Decolonial thought. She is interested in discussions involving the intersectionality of gender, sexuality, race, ethnicity, and socioeconomic status in the construction and teaching of science.

Dr. Rosa is on the board of directors of the Brazilian Physics Society. She is also a member of the American Physical Society, the American Association of Physics Teachers, the National Organization of Gay and Lesbian Scientists and Technical Professionals (NOGLSTP) and the Brazilian Association of Black Researchers (ABPN). She coordinates a large national project for building an oral history archive of Black scientists in Brazil and is one the founders of the LBsTem group, an organization for lesbian, bi and trans women in STEM in Brazil.

SCIENCE EDUCATION AS A SOCIAL MOVEMENT

Sara Tolbert

University of Canterbury, New Zealand

In the past decade, we have witnessed and experienced climate disasters, a worldwide pandemic, and countless other wicked socioscientific problems. Entangled in these wicked problems of the Anthropocene is the exacerbation of historical disparities, including racial, gender, and economic oppression. It is undeniable that socio-ecological and socioscientific problems are centrally political problems. What is the role of science and education in a complex, entangled and politicised world? Drawing inspiration from social movements of the past and present, I contemplate what science education might look like if it were (re)imagined as a social movement. What would be the implications for our professional organisations, schools, and communities? Where and with whom would our solidarities lie? I invite participants to think and dream together toward forging a new social movement for science education, in the name of life and love in the Anthropocene.

Sara Tolbert is Associate Professor in the Faculty of Education at University of Canterbury (UC) in Aotearoa New Zealand, previously Associate Professor in Teaching, Learning, and Sociocultural Studies at the University of Arizona (USA). Sara is a former science teacher and environmental educator, and has worked with students in multilingual contexts in the USA, Aotearoa New Zealand, Mexico, and Guatemala. Her scholarship draws from feminist studies, anti-colonial/critical theory, environmental humanities, science-and-technology-studies, and critical pedagogy to explore possibilities for justice through science and education in the Anthropocene(s). Some of her current projects include Postdigital Pedagogies of Care, Pāngarau Unleashed: a Multiple Case Study of De-streaming Secondary Mathematics, Freire: A Praxis of Radical Love and Critical Hope for Science Education, and Reimagining Science Education in the Anthropocene. She co-leads the Ōtautahi Food Justice Research Collaborative, a UC Community and Urban Resilience initiative, and the UC Learning for Earth Futures research cluster

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STRAND 1: HISTORY/PHILOSOPHY/ETHICS OF STEM – IMPLICATION FOR EDUCATION

ARTISTIC WAYS OF KNOWING: REINFORCING INTERDISCIPLINARY SCIENCE LEARNING

Dave Del Gobbo[1,a,!], Sheliza Ibrahim[2,b,@], Sarah El Halwany[3,c,#], Majd Zouda[2,d,$], Nurul Hassan[2,e,%], Mirjan Krstovic[1,f,^], Nicole Kofman[2,g,&], Gonzalo Guerrero[4,H,*], and Larry Bencze[2,I,+]

[1]Peel District School Board, [2]University of Toronto, [3]University of Calgary, [4]University College London

[!]dave.delgobbo@peelsb.com, [@]sheliza.ibrahim@utoronto.ca, [#]halwanysarah@gmail.com, [$]majd.zouda@mail.utoronto.ca, [%]nurul.mohammad@mail.utoronto.ca, [^]mirjan.krstovic@peelsb.com, [&]kofman.nicole@gmail.com, [*]g.hernandez@ucl.ac.uk, [+]larry.bencze@utoronto.ca

The disciplines of both art and science provide opportunities for students to contemplate issues, harms, activist stances, and attitudes of environmental sustainability and social justice. Similarly, bodies of artistic and science knowledge may create systems of knowledge that share common values. We dissect sets of values from a particular Science, Technology, Society & Environment (STSE) science pedagogy framework and discuss how these values can be taught, contemplated, and located in artistic works or introduced to students via art. A literature review of STEAM education indicated that art was integrated into STEM frequently in form of subservient roles like making STEM more attractive as a career destination for students, or as a means of improving aesthetics or creativity of school projects. The paper concludes with revisioning potential pedagogical practices in STEAM education so it may promote better environmental outcomes or catalyse sociopolitical action.

PURPOSE

Science education, as a pedagogical space for developing science literacies, has shifted dramatically amidst the COVID19 pandemic. Surface level changes include adoption of technology-driven multi-modal pedagogies. More transformative changes concern lenses through which science is taught due to several current and historical social justice issues. Global news has been, for instance, tracing: the Black Lives Matter movement, which illuminated racial inequity; Fridays for Future, which raised climate awareness; and, discoveries of Indigenous children buried at Canadian Residential schools, which raised national and global concerns for truth and reconciliation. Such challenges to humanity may also be linked to science and technology (e.g., negative health outcomes and environmental degradation from artisanal coltan mining in the Congo (Leon-Kabamba 2018), or social media platforms espousing Eurocentric ideals that infringe on Indigenous identity, and sovereignty (Matamoros-Fernández, 2017).

Dreams of more just and ecologically sustainable futures are frequently driven by *sociotechnical imaginaries*; sets of collective visions, that blueprint normalized relationships among fields of science & technology and societies & environments (STSE), including art (Jasanoff & Kim, 2009). As science progress is linked to science education, educators are tasked with decolonizing their educational practices and employing teaching philosophies aligned with social justice and environmental sustainability.

Our rationale to examine intersections between art and science emphasizes ways in which art can serve as a tool by which multiple perspectives can understand and construct alternatives for knowing in the world, while contesting more objectivist conceptions relating to science. Our curiosity is in how art forms (i.e., visual, auditory, kinaesthetic.) represent depictions of the world (i.e., ideologies of the nature of science) that, in turn, provide contemplative spaces for critical reflection, transformation and agency.

Examinations of art might serve as entry points for uncovering actants of living and non-living entities that complicate our ways of knowing. Larger systems of actants promoting shared outcomes are called dispositifs (Foucault, 2008). In this paper, the authors explore how art within science education can creatively deconstruct such dispositifs, so they are evaluated and reconstructed to prioritize social justice and environmental sustainability. This restructuring might break certain interpretations of science ideas, particularly buried truths, that are/were favoured by broader masses (Derrida, 1978). This paper will do so in the following ways:

Review the theoretical lens of the *STEPWISE* framework (Bencze, 2017) to pedagogically design activities that use art as a medium for critical engagement.

Define the STEPWISE framework and argue that the values inherent to STEPWISE and STSE can be in art forms and introduced through art.

Examine ways in which art has historically been taken up in STEAM education (Science Technology, Engineering, Art & Mathematics) and suggest that contemporary uses of art that aligns with issues of social justice and climate crises can be supported with the STEPWISE framework.

THEORETICAL LENS

In 2006, Bencze created the pedagogical framework for Science & Technology Education promoting Well-Being for Individuals, Societies & Environments (STEPWISE) (See Figure 1), which prioritized student planning/implementation of student STSE activism alongside science skills, products and student research (Bencze, 2019a, Zeidler, 2016) it was further developed for classroom use (see Figure 2) (Bencze, 2019b). This framework suggests that teachers provide students with a series of constructivism-informed 'apprenticeship' lesson and activity cycles, providing students with requisite attitudes, skills and knowledge (ASK) to perform their own research-informed and negotiated action projects ('Students' Self-led Projects) to address problematic STSE issues, e.g., a student-organized school "Red Day" to raise awareness about lack of supports for gender hormone therapy in transitioning youth (Bencze, 2019a), or through creation of eco-just engineering products, such as durable, yet biodegradable, 3D-printed tennis shoes (Bencze, 2020). STEPWISE offers a pedagogical framing for science educators to infuse art in their instruction.

Science education has called for more social and environmental connections. Indeed, Pedretti and Nazir (2011) list the currents of STSE education as Application/Design, Historical, Logical reasoning, Value centred, Sociocultural, and Socio-ecojustice. It is recommended that students develop functional understanding of complex interactions among fields of STSE (Pedretti & Nazir, 2011) as doing so may increase participation in democratic decision-making on matters involving science and technology (Winner, 1995). In this paper, STEPWISE can be considered as an example of a pedagogy aligned with the socio-ecojustice current.

Even in the effort to connect STSE in teaching and learning of science concepts, many forms of science education have become de-problematized and the complexities of STSE issues are often presented through reductionist lenses (Bencze et al., 2018; Gough, 2015; Zeidler, 2016). Similarly, many products of technoscience are virtual ‘Trojan Horses’ (e.g., a mobile phone may embody semiotic abstractions of being ‘smart or sleek’ while obscuring complex harms like conflict mineral use, or worker exploitation). This may be explained by the actor-network theory (ANT) concept *punctualization,* which describes how a complex network of relationships can be made to appear as a single entity (Callon, 1991). Drawing on ANT, STSE and how STEPWISE might inform science lesson planning, we reflect on the ways in which art can be part of the critical thinking needed when exploring science ideas.

METHODS

A research collective situated in an Ontario university consisting of an Associate professor, three graduate students, a post doctorate, an Assistant professor, and an in-service high school teacher with various sub-specializations in science and mathematics, held weekly meetings to discuss and analyse practices of teaching and learning science as a community (Wenger, et al., 2002). Over a span of eight (2hr) weekly meetings over three months, data gathered were: art and art-based strategies to be infused into the STEPWISE framework, photographs of art/science representations in local neighbourhoods, popular media and youth examples from personal teaching experiences, slideshows of curated definitions of art, and weekly agendas. Literature reviews, through key-word searches in educational research databases of STEM, STEAM, science education, ‘science and art’, social justice education, environment, *‘STEPWISE’* and articles shared among the group from their own academic connections/interests/searches, also contribute to data.

The methodological basis of this review embraces a dialogical approach where the authors critically engage with both literature and the practices of academic scholars and educators comprising of the STEPWISE collective (Creswell, 2005). Firstly, the review explored literature ranging from historical discussions of art to contemporary uses of art in science education such as the STEAM movement. The diversity of this field problematizes how art is used, for whom, and when it is used for science knowing. Secondly, the authors employed a qualitative methodology where reciprocal relationships among theory and data suggest grounded interpretations (Charmaz, 2014) that could be assigned to artforms. We aligned the artforms, first individually then collectively, to *values* inherent to the STEPWISE framework. Using this constructivist-informed grounded theory method (Charmaz, 2014), values for teaching science were abstracted over 2-3 meetings and used to analyse the art expressions during group discussions. The list of values generated are found in Table 1, and a thematic analysis was adopted.

OBJECTS AND MATERIALS

Due to privacy and ethics surrounding our data from students, this paper highlights three examples of science in artistic expressions that were shared from open resources, art depicted in encounters with science on neighbourhood walks, and photographs belonging to the research collective.

FINDINGS AND CONCLUSIONS

This paper explores art as a generator of provocations for learners to consider actants and dispositifs of scientific phenomena and to critically engage with nuanced truths of socioscientific issues like climate change and eco-justice. Using STEPWISE as a pedagogical framework to guide teaching and learning experiences, we used three artistic representations to unpack multiple ways of knowing. These examples highlight STSE issues that are deconstructed in artistic expressions of science phenomena. These pedagogical practices are where learning experiences require students to reflect, teachers to teach, or students to practice (which are the phases of the STEPWISE framework). Examples are discussed in reference to the values of STEPWISE (found in Table 1) that were discussed and agreed upon, such as ecojustice, depunctualization, cross-cultural collaboration, power, automation etc. It is not exhaustive nor complete categorizations, but a direction towards broader consciousness.

Ex. 1. Actor Network Mapping as Art Experience

Art-like representations of actor-network maps were shared to the research collective (Figure 3.) In this example, the student shows understanding of *de-punctualization*, where singular (frequently semiotic) entities are revealed as masking a web of complex actants. STEPWISE directly teaches ANT associated terms like de-punctualization, actor-network mapping (Latour, 2005) and Foucault's concept of dispositifs and power (Foucault, 2008). John Dewey defined a 'work of art' as "the work that takes places when a human being cooperates with the product so that the outcome is an experience that is enjoyed because of its liberating and ordered properties" (Dewey, 1934, p. 214). The research collective considered if a student's actor-network map (Figure 4) had qualities requisite of a 'work of art', considering Dewey's definition and the knowledge that the student's own ASK towards their chosen socio-scientific issue (community water fluoridation) changed after map completion. Student generated artifacts that straddle the domains of both art and science may have pedagogical implications for meaning making to visualize complex eco-justice implications.

Ex. 2. Semiotic Interpretations of STSE Issues

An untitled image from Christoph Niemann's Instagram space was produced featuring an abstract cityscape with a central tower (see Figure 5). The artist describes the process of abstract painting as 'getting rid of anything unessential to your point' (Neville, 2017). When asked to guess the painting's geographical location, every participant chose Toronto, Ontario, a place in which many of us have spent significant time, its skyline punctuated by the CN tower, whose form is a semiotic of the city. The painting's actual subject is Berlin, Germany, the artist's home, whose cityscape features the Berlin Television Tower, who's abstraction resembles the CN tower. In an attempt to identify the art icon created by Niemann, the shared context generated by the life experience of the team lead to a misconception in the interpretation of the original object. (Pierce 1999). Similarly, science data are often decontextualized when visualized in such a way as to seem objective and neutral, a 'god's eye view' to see everything from nowhere. In practice, this means that even the most neutral science visualizations often take on the perspective of the socially dominant group (D'Ignazio, 2020). STEPWISE directly teaches students to use a World↔Sign schema (Figure 6) originally based on (Roth, 2001), so that they may be more aware of important contextual information and ontological (and ideological) gaps linked to their STSE issue. This example suggests future pedagogical methods need to increase student understanding of difficult-to-discover concepts of reductionism, ontological/ideological gaps, and semiotics.

Ex. 3. Art Provocations of Environmental Issues

A 2005 Burtynsky photograph of a manufacturing plant in Zhangzhou, Fujian Province (see

Figure 7) is also featured in a film that The New York Times claimed made the ravaging of nature seem 'disturbingly sublime' (Dargis 2007). The juxtaposition of the aesthetics of beauty with that of science progress offers critical engagement with the nature of science (Blades, 2015). Considerations of place, economic activity and material usage raise topics for teachers to introduce environmental impacts of consumerism. *Power,* such as ways in which economic demand may affect political spheres and labor markets, and *automation* such as technologies like coding for machine work, and quality assurance can also offer critical learning.

SCHOLARLY SIGNIFICANCE

This study is timely. Ladson-Billings (2021) suggests the COVID-19 pandemic, the pandemic of systemic racism, the economic crisis, and the climate crisis, as the four pandemics of our time.

Defining what constitutes 'art' is a tensioned and blurred discourse among our collective. Indeed, in literature, no definitive conceptualization of art was evident. Drawing on our review, conceptions of art within STEAM were *slanted*, noting "the predominance of Anglo-centric literature, partly as a result of the language medium adopted by international research journals, and partly due to the cultural roots of STEM, with which STEAM is often associated" (Colucci-Gray et. al., 2019 p. 6), leaving us with a gap in the literature. In our review STEAM education points to a more centralized focus on visualization, beauty and creativity, making science accessible to girls (Quigley and Herro, 2016) and increasing employability in science careers. Therefore, there was limited (but not definitive) foci on well-being for individuals, societies, and environments through lenses of social justice and sustainability - which highlights the gap in our review. This study piques critical awareness towards pedagogical practices (i.e.., use of STEPWISE and art) in science education that address involvement of multiple constructions, perspectives, and silenced voices. The values suggested in this study may offer critical lenses towards citizenship in just societies and stewardship for our environments.

This work may interest various stakeholders; higher education to study science programming that prioritizes environment and social justice issues; educational researchers to consider racial and ethnic minority groups in their exploration of history, nature of science, climate issues; policy makers to attract highly qualified teachers to schools with complex backgrounds committed to promoting well-being for individuals, societies, and environment; and teachers and professors implementing art forms in science and environmental instruction.

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APPENDIX

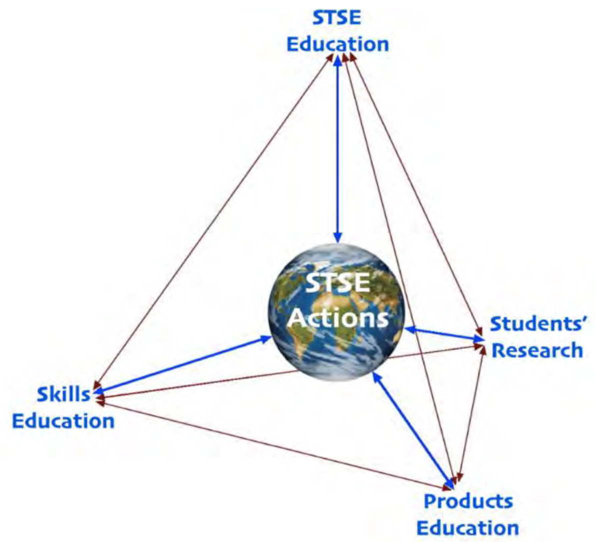

Figure 1. Theoretical framework for STEPWISE which prioritized student STSE actions at the central location in a tetrahedron of science skills, products, STSE and student research.

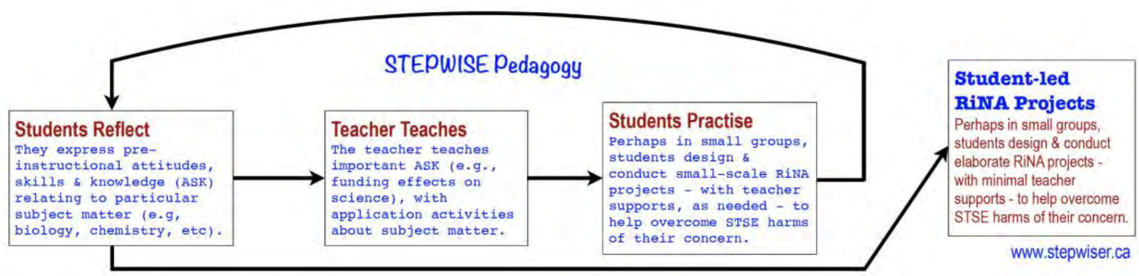

Figure 2. The 3 cycles of the STEPWISE pedagogy, & Student-Led Action via projects

I. *Students Reflect - student-directed (with teacher stimuli) and open-endless*	- subconscious (i.e., making self-conscious) - introspection - place (reflections on networks) - attitudes - skills - knowledge - equity, diversity, inclusivity (EDI), empathy, celebrated, - open-mindedness - metacognition (likely second cycle)
II. *Teacher Teaches*	- stratification - World ↔Sign - power - automation - reductionism - psychopathy/sociopathy - dispositif - education (value) about semiotics - normalization - WISE harms - pluralism; e.g., multiculturalism - altruism - de-punctualization - holism (e.g., Gaian) (vs. anthropocentrism) - collectivism - social justice; economically; identity politics - environmental sustainability; balances; limited or no growth - personalization (knowledge duality) - responsibility
III. *Students Practise - teacher/student-directed and open-ended*	- mentoring - collaboration; cross-culture collaboration. - negotiation - ethical epistemology (studies vs. experiments) - networked actions - dispositif - art of compromise - improvisation, creativity, innovation, invention, bricolage - counter-cultural (non-mainstream) ways of knowing - inscriptions (from actor network theory)
Student-led Actions	- personalization - autonomy

Table 1. Values, Concept inherent to the STEPWISE pedagogy

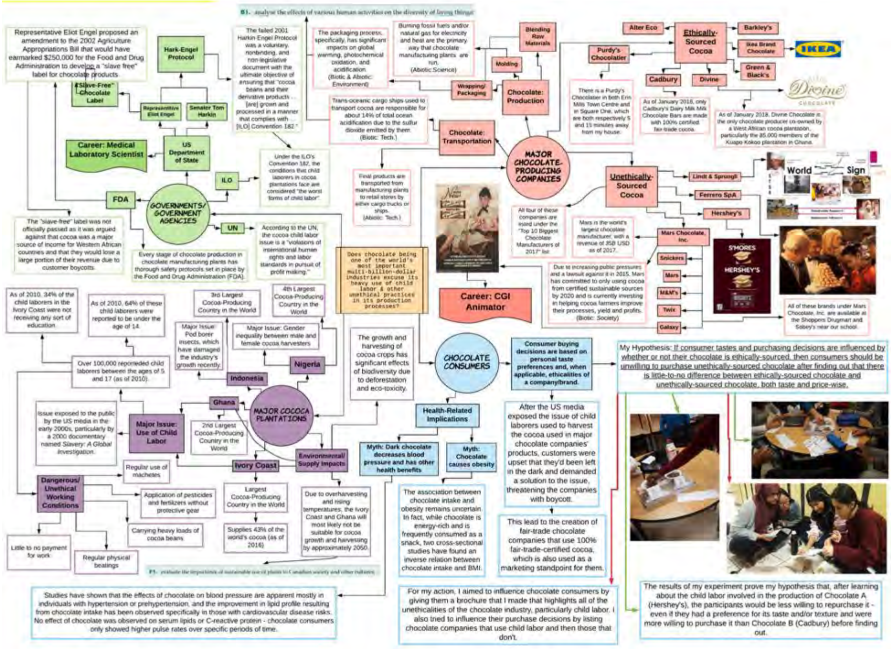

Figure 3. Student Generated Network Map

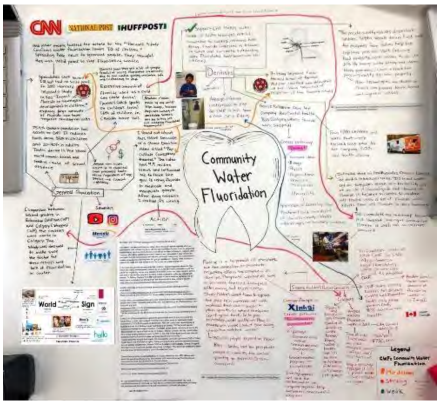

Figure 4. Student Generated Network Map of Community Water Fluoridation Policies which changed the student’s perception of their SSI.

Figure 5: Abstract painting of a cityscape with a large central tower.

Figure 6: World ↔ Sign Schema

Figure 7: Manufacturing #18, Cankun Factory, Zhangzhou, Fujian Province, China, 2005

PROMOTING CRITICAL MATHEMATICAL LITERACY

Nadia Stoyanova Kennedy

City University of New York

nkennedy@citytech.cuny.edu

Contemporary critical mathematics education researchers point out that mathematical literacy, if solely understood as acquiring mathematical and technological knowledge, is limited in promoting democratic competencies. In respect to mathematics education, such literacy should include an analytical dimension that facilitates a critique of mathematics in its philosophical and social implications. In this paper, I examine Ole Skovsmose's notion of reflective knowing as associated with critique, and its relation to Dewey's account of reflective thinking and the inquiry process. I suggest that philosophical inquiry offers a vehicle for conducting such a critique, and briefly outlined possible directions for communal and collective deliberations in a classroom setting designed to facilitate such an inquiry. I conclude that philosophical inquiry as a complement to existing mathematical practice in the classroom promises to provide another, crucial dimension to mathematics education, in that it represents a vehicle for questioning and critique and offers a discursive and pedagogical space dedicated to developing an enriched and expanded view of mathematics, and a deeper understanding of its connections to other school disciplines, to society, and to self.

INTRODUCTION

Critical mathematics education understands the development of critical mathematical literacy as an essential education task. Ole Skovsmose develops the concept of *mathemacy* — "… a radical construct, [which] has to be rooted in the spirit of critique and the project of possibility that enables people to participate in the understanding and the transformation of their society, and therefore . . . a precondition for social and cultural emancipation" (1994, p. 27).

Many researchers have expounded on the importance of reflective awareness in the role of mathematics, given its increasing influence in our highly technological society and the dangers of neglecting to develop such awareness (e.g., Davis & Hersh, 1986; Skovsmose, 1994; D'Ambrosio, 1999; Ernest, 2018). However, Skovsmose (1994) points out that reflective knowing is not an ingredient of mathematical or technological knowledge, as its focus lies outside them. An understanding of the role of mathematics and the use of its formal methods in society are not to be found *in* mathematics. We need to look "beyond" mathematics for discursive environments that cultivate reflective knowing, and for instruments that can be helpful in understanding the role of mathematics in reading and understanding the world. In this presentation, I examine more closely the concept of reflective knowing, and argue that philosophical inquiry in collaborative group settings may be an appropriate vehicle to facilitate critical reflection in the classroom focused on the understanding of the role of mathematics in society, and the implications of using mathematical and technological knowledge in addressing social problems. I then offer a brief description of what philosophical inquiry is, the context in which it is conducted and outline some possible directions for engaging school students in encounters with contestable questions related to mathematics and its role in society.

ON REFLECTIVE KNOWING

Skovsmose's (1994) notion of *mathemacy* is akin to Paolo Freire's notion of critical literacy (2005). The latter has a socio-political dimension, in that it presupposes an awareness of the complexity of socio-political and ideological forces, of the functions of power, and of the universal problem of injustice. Critical literacy relies on dialogue, reflection and pointed analysis of controversial and important issues in students' lives. Such dialogues function to expose students to multiple perspectives and engage them in a critique of oppressive structures, in the interest of gaining a deeper understanding of the social and political forces that drive them. In this sense, critical consciousness or *"conscientização"* (Freire, 2005) is as much about raising awareness as about empowerment, here understood as the ability to act in the world in the interest of changing it.

Similarly, Skovsmose's (2007) vison of *mathemacy* as a competency is not solely functional--that is, about learning mathematics in order to use it in one's personal and professional life. It is also a critical competency--one that allows people to engage in "reading the world" through an emancipatory lens, using mathematics to question deeply seated assumptions and beliefs, examine implicitly held values, "talk back" to authorities, and imagine alternatives. Mathemacy is understood as empowering---a competency that opens the door to active participation in a democratic society.

As formulated by Skovsmose (1994), *mathemacy* includes mathematical, technological and reflective knowing. Mathematical knowing "refers to the competencies we normally describe as mathematical skills," and technological knowing "refers to the ability to apply mathematics and formal methods in pursuing technological aims" (p. 100-101). The latter relies on mathematization--the interpretive act of modeling real world phenomena in purely mathematical terms. Skovsmose argues that mathematical and technological knowledge—the tools of mathematization--are limited in addressing the concerns of critical mathematics education. In fact, in his view mathematics as a field of knowledge has a "formatting power" that structures all aspects of social life in non-transparent ways. He suggests that reflective knowing is necessary to counter the covert effects of this hegemonic epistemological power:

[The] fundamental thesis relating technological and reflective knowledge is that technological knowledge itself is insufficient for predicting and analyzing the results and consequences of its own productions; reflections building upon different competences are needed. The competence in constructing a car is not adequate for the evaluation of the social consequences of car production. Improved road ability does not lead to a better understanding of motoring. Technological knowledge is born 'shortsighted' as it were. (Skovsmose, 1994, p. 99)

Reflective knowing, he argues, "has to do with the evaluation and general discussion of what is identified as a technological aim and the social and ethical consequences of pursuing that aim with selected tools" (p. 101). It represents the competence required for the ability to "take a justified stand" in a discussion that concerns technological questions (p. 101). Such a description of reflective knowing makes it akin to a manner of thinking that John Dewey describes in his book *How We Think* as constitutive of *"active, persistent, and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it, and the further conclusions in which it tends"* (1910/1997, p.6, emphasis in original). Reflective thinking is different from ordinary thinking in that it is aware of the grounds for its beliefs as well as their consequences. Dewey associates reflective thought primarily with scientific knowledge, in that for him "science is the perfecting of knowledge, its last stage" (1916, p. 219); as such, he advocates for a form of education fashioned on the model of critical inquiry.

Some of the concerns of critical mathematics education are related to "issues of social availability of mathematical knowledge" (Geller & Jablonka, 2007, p. 1). Mathematization often renders the mathematical processes involved invisible and its processes and results more difficult to question. We are increasingly faced with what Keithel, Kotzmann and Skovsmose (1993) refer to as "implicit mathematics," the bases of which are not visible. Technology functions as a "black box" of implicit underlying mathematical processes that are "frozen" in objects and technological structures and apparatuses (Gellert & Jablonka, 2007). Such processes help increase gaps between "experts" and non- "experts," between the designers who understand these structures and the rest who cannot, thus reinforcing antidemocratic divisions between an "expert" elite and consumers (Skovsmose, 2007). Since these kinds of processes tend to preclude democratic participation, excavation of "frozen' mathematics and the development of appropriate tools for understanding them become a paramount issue.

Although some types of reflective knowing associated with mathematical problem solving and modelling are grounded in mathematical and technological knowledge, some types extend beyond their boundaries. These concern a critique of the social consequences of enacted mathematics, and require a close examination of the assumptions, values, norms, and ethics that are implicit in the mathematization process. Inquiry into such questions and concerns qualify as philosophical rather than mathematical and require philosophical rather than mathematical judgements. Thus, I suggest that philosophical inquiry can act as a vehicle that facilitates reflective knowing in the mathematical domain. Next, I will explore one practical form of philosophical inquiry in educational settings that lends itself particularly well to this project.

PHILOSOPHICAL INQUIRY

For a model for conducting philosophical inquiry, we turn to a program founded in the 1970's and internationally known as *Philosophy for Children* (P4C)[1]. The program uses a pedagogical format known as "community of philosophical inquiry" (CPI) (Lipman, 2003), conceptualized as a communal dialogical process that bases its practice on philosophical questions and concepts generated by students themselves in response to a stimulus in the form of a text or other media. The program founders developed a curriculum consisting of philosophically provocative stories written for children and thematized teacher manuals that focus on central, common and contestable concepts found there, such as friendship, freedom, justice, beauty, persons, mind, body, authority, conflict, truth, "real," "alive", etc. (Lipman, 1981; Lipman, Sharp, & Oscanyon, 1980). Although, they did not envision philosophical discussions focused on questions concerning mathematics or its impact on society, I suggest that the methodology (not the curriculum per se) can be used to engage students in critical examination of the role of mathematics in society, as well as mathematics in general – in other words, to conduct meta-mathematical reflections through dialogical inquiry.

In a classroom, the philosophical discourse in question is reconstructed as more practical and more accessible to students than is traditionally the case. The inquiry begins with some kind of problem which gives rise to a more general philosophical question--what is the most reasonable thing to believe or to value or to do in this case? -- and ends in some kind of satisfactory

[1] For more information about the Philosophy for Children (P4C) program see: the Institute for the Advancement of Philosophy for Children (IAPC, https://www.montclair.edu/iapc/); the International Council of Philosophical Inquiry with Children (ICPIC, https://www.icpic.org/), Philosophy Learning and Teaching Organization (PLATO, https://www.plato-philosophy.org/).

resolution or fulfillment in the nature of a judgment. The latter tends to be a proposition about what should be believed or valued or done with regard to the original problem. In P4C methodology, inquiry begins with students generating questions based on a reading of an excerpt of a curricular novel, followed by determining the group's interests and creating an agenda for discussion.

Philosophical inquiry focuses on "big questions" (Wiggins & McTighe, 2005) or *common*, *central* and *contestable* (CCC) questions (Splitter & Sharp, 1995): common to all humans in some form, central to our understanding of ourselves and of the world, and contestable, as they do not have one simple answer. They are also questions that lend themselves best to communal, collaborative deliberation in a setting in which participants are engaged in putting forward and evaluating arguments and arriving at reasonable judgments as to those arguments through dialogue. Philosophical inquiry so understood relies on the Deweyan proposition that ethical, aesthetic, political, and other philosophical dimensions describe facets of most people's ordinary experience rather than some esoteric experiences separated from the ordinary (Dewey, 1934; Lipman, 2003). It also takes on Dewey's notion that inquiry should connect to student's own questions, and respond to genuine perplexity and doubt (Dewey, 1910/1997).

In the context of the mathematics classroom, philosophical inquiry can serve as a vehicle for an inquiry focused on contestable questions that are not discipline-specific, but act to question the outcomes of the uses of mathematics in society. Some examples of questions might be "What part does mathematics play in the way we organize our lives?" or questions related to social justice, such as "What is fair wealth distribution? How should wealth be distributed?" These can be qualified as philosophical questions to the extent that they explore political and ethical dimensions of our experience with mathematics. Such a project draws heavily on Dewey's idea that inquiry should begin with a particular experience—in this case an experience that involves a mathematical activity. The mathematical activity makes for a shared group event, and the problematization that follows in the discussion can motivate students to inquire further in a search for answers to related, relevant, contestable questions. In other words, the mathematical activity acts to structure the inquiry that follows it, or to use Dewey's term, to "occasion" it.

In my own experience with conducting philosophical inquiry in the context of a mathematics classroom, I have used written texts about mathematics or posed mathematical tasks, the experience of which occasions the generation of students' philosophical questions (e.g., Kennedy, 2012; 2018, 2020). What is seen and felt as problematic and perplexing must reflect the experiences of the group of students-not only those experiences related to the mathematical activity, but previous personal school and out-of-school experiences as well. Above all, the initial goal of inquiry with contested questions related to mathematics is to help students reflect on and challenge deep-seated assumptions, critically explore values and social practices, and discuss social alternatives.

POSSIBLE DIRECTIONS FOR PHILOSOPHICAL INQUIRY IN THE CLASSROOM

Here we outline a few possible directions for conducting philosophical inquiry in the classroom. Philosophical inquiry can also serve to furnish a more global perspective regarding mathematics, its nature, its aesthetic and ethical dimensions, and the cultural and political implications of the uses of mathematics in our society. To include opportunities in the curriculum for aesthetic inquiry into mathematical concepts through exploring phenomena like symmetry, fractals, patterns, and more offers the possibility of expanding student powers towards not only the appreciation of mathematical beauty, but also of developing criteria for aesthetic judgment in general. Inquiries into questions such as "Is there a connection between symmetry and beauty?" "When is a pattern beautiful?" "What is an elegant math solution or proof?" and others not only may prompt students to think about math concepts in new ways, but also offers them the freedom of opportunity to relate to mathematics itself in a new way, and to have new experiences of "relatedness" that go beyond the current utilitarian concerns of the curriculum and its characteristic texts.

A major portion of the current school mathematics curriculum is devoted to utilizing or developing mathematical models that represent and can usefully describe a situation, and which allow further manipulation of the model in order to make predictions. There is, however, little awareness of how those models correspond to the real-world situations they model, and what the implications of those relationships are. A mathematical description always involves simplification and the making of assumptions on the part of the creator of the de- scription (Shapiro, 2000). A mathematical description or model cannot, therefore, fully explain a nonmathematical situation or event without some account of the relationship between mathematics per se and scientific reality. Thus, a philosophical inquiry into the nature, uses, and inherent limitations of mathematical models, and into the implications of the use of such models in our social and practical lives, is necessary in everyday mathematical practice, lest we become captives and victims of those uses and limitations. It is not enough to know how to use models—students also need to understand and know how these models shape and control our everyday lives. For example, the quantification of knowledge through different evaluation models, of which the SATs are prime examples, raises questions not only regarding unstated epistemological assumptions and values; it also leads us to critically examine the role of mathematics in social reproduction, in determining social practices, and in organizing everyday experience. Those determinations follow on the general social and material blueprint of mathematics as a system and method, and they prefigure not only the mode of access to those products of mathematization, but also the mode of studying, using, interpreting, and evaluating them; thus, mathematics also acquires prescriptive and symbolic power (Davis & Hersh, 1986; Skovsmose, 1994). Unless these aspects of mathematics as we practice it are brought into the open and discussed, there is an obvious danger of our students turning into uncritical consumers of mathematics with little or no understanding of the worldview it reinforces, and with no critical competence to judge mathematical productions and prescriptions.

Yet another inquiry that may have far-reaching implications for the development of the critical mathematical subject, and the prospects for the emergence of a truly autonomous citizenry, is epistemological. "Personal epistemology," a term now commonly used to denote personal beliefs about knowledge and knowing (Kuhn, Cheney, & Weinstock, 2000), is increasingly recognized as a powerful hidden shaper of student expectations and learning practices, and thus as crucial for individual learning and development. In Dewey's terms, beliefs are habits that inform future action, but they are also susceptible to change through experience. For math learners, implicit and often unconscious beliefs about self in its relation to mathematics—about knowing, learning, and doing mathematics, about the social context of learning and doing mathematics, about the accessibility or inaccessibility of mathematics as a discipline, about its inherent value, usefulness or intrinsic interest—all of these make a crucial difference for success or failure in the classroom, and experiences that challenge negative beliefs and habits and render them inadequate promise to be transformational. A form of epistemological inquiry that prompts students to reflect and deliberate together on questions like "Can I become a better thinker? If so, how?" "Can one be a good mathematician without knowing it?" "How do I know that I know or don't know mathematics?" "How does one get to know mathematics?" "What does it mean to know mathematics?" "What is mathematical understanding?" "What kind of a math learner am I?"—such an inquiry may represent a form of educative experience that challenges tacit assumptions and inherited beliefs about the nature of knowing, understanding, and learning, and is, as such, a powerful tool for the reconstruction of belief.

IN CONCLUSION

Many proponents of critical mathematics education understand the development of critical mathematical literacy as one of the essential problems of democracy, which, in their opinion, should match mathematical and technological development. If participation in a democratic society is not restricted to following formal procedures of elections and government, but is understood as participating in direct democracy or, in Deweyan terms, as "a mode of associated living," then citizens should be able to critically appraise and scrutinize not only the mathematics instrumentarium, and its results, but also the implications of its use. I have suggested that philosophical inquiry offers a vehicle for conducting such a critique, and briefly outlined possible direction for communal and collective deliberations in a classroom setting designed to facilitate such an inquiry. Conducting philosophical inquiry as a complement to existing mathematical practice in the classroom promises to provide another, crucial dimension to mathematics education, in that it represents a vehicle for questioning and critique of mathematics and offers a discursive and pedagogical space dedicated to developing a critical mathematical literacy.

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REGIONAL DISPARITIES IN EDUCATIONAL OPPORTUNITIES IN KERALA

Muhammed Kutty P. V.[1,a,!], Ahmed Ashraf Z. A.[2,a,*], Fajrul Ihsan P. V.[3,a,#], Hashim N. K.[4,a,~]

[1]Govt. Higher Secondary School, Agali, Palakkad, Kerala

[2]Govt. Arts and Science College, Calicut, Kerala

[3]Madras School of Economics, Chennai, Tamil Nadu

[4]WMO Arts and Science College, Muttil, Wayanad, Kerala

[a]he/him/his

[!]mk.egrl.iig@gmail.com, [*]zaamail@gmail.com, [#]fajrulihsanpv@gmail.com, [~]hashimphysics@gmail.com

Kerala Model has been much celebrated a model of development, universal education and health care being the highest achievements of the state. The study found that the distribution of educational opportunities funded by the public money (government/government aided institutions) is not unbiased. Huge disparity exists in the opportunities available in the Southern districts and in the Northern districts of Kerala. While the Southern districts enjoy enormous choices, the Southern districts are starving for sufficient opportunities. The North - South divide increases as the level of education goes up from primary school education to higher education.

INTRODUCTION

Kerala is a state in the Southwest coast of India that contain 14 districts, 78 Taluks, 941 Grama Panchayaths, 6 Corporations and 87 Municipalities. Kasaragod (KSD) is the Northern most district of Kerala which was part of South Canara district during the British Era. Kannur(KNR), Wayanad (WND), Kozhikode (KKD), Malappuram (MPM), Palakkad (PKD) and much of Trissur (TSR) districts of present day Kerala were part of Malabar district in Madras presidency during British era and Madras state post independence. Travancore and Kochi were two princely states during the British era, that later merged into a single Thiru-kochi state post independence. Present day Ernakulam (EKM), Kottayam (KTM), Idukki (IDK), Alappuzha (ALP), Pathanamthitta (PTM), Kollam (KLM) and Thiruvananthapuram (TVM) districts in Kerala were part of this Tirukochi state that existed till the formation of the state of Kerala on 01 - November - 1956. In the present study, Malabar means the seven northern most districts and Tirukochi means the seven southern most districts of Kerala.

The division of administrative units in the state of Kerala is such that the average area of a district in Tirukochi is 2623 sq.km where as that for Malabar is 2927 sq.km and the average population per district is 22,62,459 for Tirukochi and 26,84,711 for Malabar. This means that the division of administrative units are not according to the population. This kind of disparity is visible through out most of the indices including education and health infrastructure that give a direct idea on the existing bias in public expenditure. For example, Tirukochi has 11 General hospitals whereas Malabar has only 7 as per the department of economics and statistics, government of Kerala (http://www.ecostat.kerala.gov.in/index.php/health-state-ksd) even though as per the 2011 census, only 46% of the population of Kerala reside in Tirukochi region and 54% reside in Malabar region.

In the education sector, the impact of disparity has heavier impacts especially in a state like Kerala where the literacy level and universal school education goals are already achieved. When the set goal is achieved and there exists a huge disparity, it means that there is a lot of wastage of public money in regions with high achievements. This is one important aspect we would like to bring out through the present study.

According to the data published in *Sametham* (https://sametham.kite.kerala.gov.in/) in 2021, 35.8% of students in class 1-10 are in the 7 southern districts collectively called Tirukochi and the remaining 64.2% in the 7 northern districts collectively called the Malabar in the present paper. This idea about the share of population in these two regions is very important to understand the statistics discussed in the present paper and is also a very important indicator while acting upon fresh release of funds for establishing new institutions and courses.

The present study presents the share of various educational opportunities in Malabar and Tirukochi. As right to education has provided universal access to education, every children in Kerala is offered the opportunity to get the school education. But there is a huge regional disparity in the way the educational opportunity is provided to the students.

The points to be noted about this present study are:

i. Only those schools/institutions/colleges where the salary of employees are paid by the state government (government owned & government aided private institutions) are considered in the study for calculating the opportunities available. Therefore the present article highlight the bias that comes exclusively from the government side. As institutions are set up over a long period of time, the disparities presented shall be considered to be historical and not any failure from the present government.

ii. Private institutions that collect fee (called self-financing or unaided institutions) from students are not considered in the study as such institutions are supported by the students themselves and the state do not have a role in their funding.

The data used in this study is for the academic year 2020 - 2021. As there was no considerable shutting down of institutions over the decades and there were addition of new courses, batches and institutions, the data is the information of opportunities that are accumulated over the past several years.

DATA: SOURCES AND METHODS

In the present study, the educational opportunities with respect to the available student population in the academic year 2020 - 2021 is used. The data required for the study are accessed from the websites of the departments/agencies concerned. The *Sametham* website gives detailed data of the school education in Kerala from class 1 to 10 that include information regarding number of students and staff, details of available infrastructure, location in latitude and longitude and administrative units of which the schools stay part of (https://sametham.kite.kerala.gov.in/). The list of courses available in each higher secondary school in the state can be accessed from the site *HSCAP* (https://hscap.kerala.gov.in/) and that of vocational higher secondary school can be accessed from the website *VHSCAP* (https://vhscap.kerala.gov.in/vhse_cms/index.php). Details of institutes, courses and intake of the state's industrial training institutes funded by the government can be accessed from their website via the prospectus of admissions 2021 (https://det.kerala.gov.in/index.php/98-admission-2016/255-ncvt-admission). Data of the courses available in each Polytechnic college and intake for each course are available in the website, (https://www.polyadmission.org/index.php?r=site%2Fhome). The details of UG and PG seats in the colleges owned by government, privately owned and funded by government and self-financing are available in the respective university admission portals as well as in the website of directorate of collegiate education. The four universities; Kannur University (https://www.kannuruniversity.ac.in/en/,) Calicut University (https://admission.uoc.ac.in/), Mahatma Gandhi University (https://www.mgu.ac.in/programmes/) and Kerala University (https://www.keralauniversity.ac.in/home) act as the affiliating universities. The data used in the present study was accessed from (http://collegiateedu.kerala.gov.in/?page_id=1834).

There are other non-affiliating universities such as Malayalam University, Sanskrit University, Cochin University of Science and Technology Digital University, universities that affiliate professional colleges and central institutions. These are not considered in the present study, because the present study would like to focus on the opportunities for the masses that are catered by schools, ITI's, Polytechnic colleges and Arts and Science Colleges.

KERALA: RELEVANT BACKGROUND

The structure of school education in Kerala is as follows: lower primary (Class 1 to 4), upper primary (Class 5 to 7), high school or secondary (Class 8 to 10) and higher secondary/vocational higher secondary (Class 11 to 12). There are no public exams till tenth standard at the end of which the state wide secondary school leaving certificate (SSLC) examination is conducted by the state board. Based on the grades and other bonus points obtained in extra curricular activities, admission to 11^{th} class is given to the students through a state level online centralized allotment program separately to higher secondary or vocational higher secondary stream. In the vocational higher secondary stream, an additional vocational training is given to the student.

Figure 1: The educational levels in Kerala. Most of the students prefer to continue to 11th and 12th classes after their 10th. A lot of students also join polytechnic colleges too. Industrial training institutes are preferred by students who are very eager to go for jobs. The detailed number of seats and institutes available are discussed in the following sections.

After 10th class, the students in general opt for any of the four streams of higher level education as shown in the Figure 1. They may go for higher secondary or vocational higher secondary courses to complete 11th and 12th classes; that's what most of the students prefer, some go for three year Polytechnic diploma courses or an Industrial Training course that is 1 - 2 year long.

The district wise share of students in classes 1 to 10 (Sametham) is in Kerala is given in the Table 01. The share of students studying in classes 1 - 10 in the Malabar districts is 64.2% of the Kerala aggregate. Thus it is expected that the educational opportunities in Kerala would be distributed such that 64.2% of all the opportunities are in the Malabar region.

	District	**Total Students (G+A+U)**	**Student Share(%) [Class 1 -10]**	**Region Share**
Tirukochi Region	Thiruvananthapuram	317653	8.1	35.8%
	Kollam	265175	6.8	
	Pathanamthitta	89762	2.3	
	Alappuzha	189151	4.8	
	Idukki	162282	4.1	
	Kottayam	104407	2.7	
	Ernakulam	272094	7	
Malabar Region	Thrissur	333906	8.5	64.2%
	Palakkad	365258	9.3	
	Malappuram	774959	19.8	
	Kozhikode	406299	10.4	
	Wayanad	114158	2.9	
	Kannur	326077	8.3	
	Kasaragod	191033	4.9	
	Total	3912214	100	100

Table 1: Table showing the district wise distribution of student population (Class 1 - 10) in Kerala (As per 2020 - 21 data accessed from *Sametham*). The numbers are inclusive of Government Owned (G), Government Aided (A) and Unaided (U) schools.

This data is very important in a futuristic way of understanding the present condition. Instead of focusing on what happened in the past, what compensation has to be done for the future has to be considered with utmost importance. This is what we mean by the term 'futuristic way of understanding the present'. The fact that 64.2% of the students in the classes from 1 to 10 in Kerala are from the Malabar region has to be considered while allocating new courses and institutions.

SURVEY OF AVAILABLE EDUCATIONAL OPPORTUNITIES IN KERALA

Primary and Secondary Schools.

The district wise number of lower primary, upper primary and high schools in Kerala state are given in the Table 2 along with the management type. The publicly funded free education is given only in the first two categories - the government owned schools (G) and the government aided private schools (A). The table also gives the number of schools that are not aided by the government and run by collecting fee from the students as an additional information. Such schools are called unaided schools (U).

From the Table 2 it is clear that out of the 6645 lower primary schools, 2737 upper primary schools and 2699 high schools in Kerala that are funded publicly, only 56.7%, 58.2% and 44.6% respectively are available in the Malabar districts though 64% of the total students in classes 1 - 10 are from these seven districts. The problem is severe in the case of high schools. Due to the lack of enough high schools, the existing high schools are highly crowded in the Malabar region. On the contrary, school in the Tirukochi region are struggling to get children. The data clearly indicate that the schools in Malabar are much more crowded than those in the Tirukochi region.

	LP Schools				**UP Schools**				**High Schools**			
District	**G**	**A**	**U**	**Total**	**G**	**A**	**U**	**Total**	**G**	**A**	**U**	**Total**
TVM	311	173	25	509	100	98	26	224	132	97	93	322
KLM	275	179	40	494	66	132	26	224	90	127	46	263
PTM	167	229	27	423	43	87	14	144	53	112	16	181
ALP	199	187	26	412	68	79	12	159	66	127	24	217
KTM	172	256	26	454	63	132	14	209	74	169	44	287
IDK	172	125	21	318	25	61	5	91	85	70	18	173
EKM	184	248	30	462	88	101	23	212	116	177	80	373
TSR	121	370	35	526	56	163	9	228	89	151	44	284
PKD	196	349	25	570	44	160	24	228	94	79	50	223
MPM	368	488	42	898	94	230	38	362	113	89	141	343
KKD	182	527	30	739	70	239	20	329	83	102	58	243
WND	91	47	9	147	21	41	7	69	62	27	18	107
KNR	117	605	12	734	67	279	24	370	103	79	34	216
KSD	195	112	15	322	60	70	30	160	98	35	35	168
Total	**2750**	**3895**	**363**	**7008**	**865**	**1872**	**272**	**3009**	**1258**	**1441**	**701**	**3400**

Table 2: The district wise number of lower primary, upper primary and high schools in Kerala state. The management type is indicated as; G: Government Owned, A: Government Aided and U: Not aided by the government.

The *crowdedness* of a high school has many undesirable effects on the personality development and future of the students as well as the quality of education they get due to several reasons. Firstly the available facilities per student becomes lesser and lesser in huge schools unless these have very strong management capable of grabbing their due share. There are about four hundred items of extra curricular activities through which students get bonus point that help them secure admission to higher studies and employment. Also even a school level win in an extra curricular item would be a great confidence booster to the students. In any event, the number of school level winners are limited in Malabar region due to the large sample size. It is also a loss to the nation, as the talent pool is masked at the root itself. For example, if a school have two equally competitive athletes, only one would go ahead to the next levels leaving the other one into a total disappearance. Such miseries are most probable to schools with large number of students.

One indicator to estimate the *crowdedness* of high schools in a precise manner is to count the number of number of students who appear for the secondary school leaving certificate (SSLC) examination. The right panel of Figure 2 shows the district wise number of schools in which at least 500 students appeared for the SSLC examination. The left panel shows the district wise number of total schools in which only less than 20 students appeared for the examination.

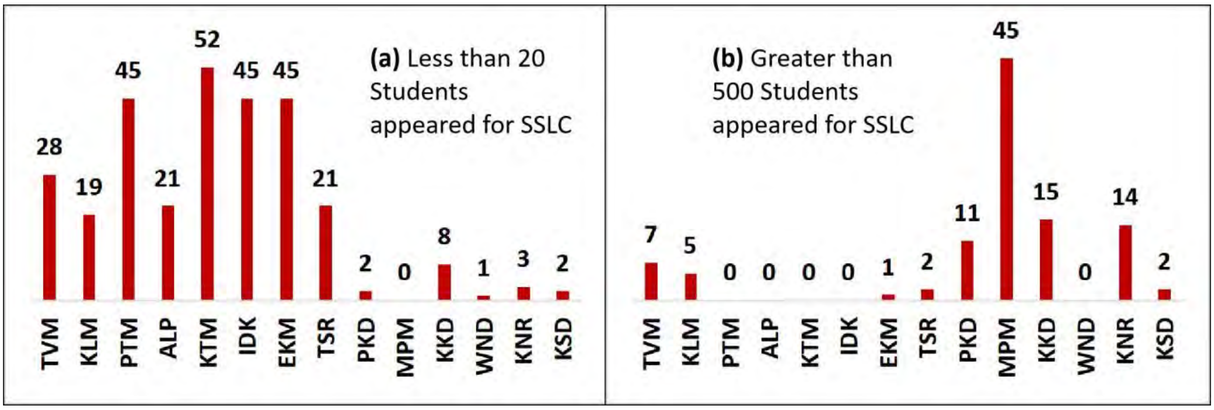

Figure 2: (a) The district wise number of schools in which a total of 20 students or less appeared for the SSLC examination in Kerala. (b) The district wise number of schools in which a total of 500 students or more appeared for the SSLC examination in Kerala.

The Malabar - Tirukochi disparity is very clear in the Figure. The fact that 87.2% of crowded schools are in the Malabar (panel (b)) region is a clear indicator of the prevailing undesirable condition. On the contrary, 87.3% of publicly funded schools with lowest number of students (less than 20) are in the Tirukochi region. Out of the nine schools where more than 1000 students appeared for SSLC examination, all except one are in Malabar region. Such extreme disparities when averaged give a decent picture of the state of Kerala; though the prevailing inequality within the state is extreme. To cite an example, a total of 2075 students appeared for the SSLC examination in 2021 March in the school PKMHSS Edarikkode in Malappuram district. On the contrary, the Kuttanad educational district in Alappuzha district which has 33 schools, only 2047 students appeared for the examination. The disparity has become so severe that a school in Malabar region is to be compared with an educational district in Tirukochi region.

Educational Districts

The formation of educational districts, a very important unit of educational administration is supposed to be based on the number of students. But unfortunately, the disparity in the number of Educational Districts is very huge. The Figure 3 shows the number of students per educational district for each district in Kerala. The disparity may be made clear by using the number of students appeared for the SSLC examination. The total number of students that appeared for the SSLC examination - March 2021 in Malappuram Educational District is 13 times more than the number that appeared in Kuttanad Educational district (in Alappuzha district). Thus it is confirmed that there is high disparity between Malabar and Tirukochi regions in the number of educational districts as well.

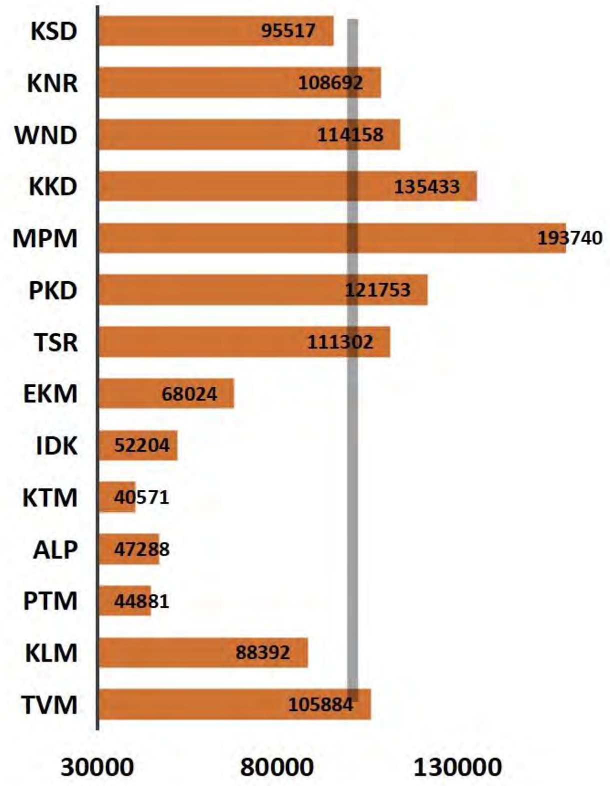

Figure 3: Average number of students in an educational district for each district in Kerala.The gray vertical line shows the state average.

Higher Secondary, Vocational Higher Secondary, ITI and Polytechnics.

Higher secondary, vocational higher secondary, ITI and Polytechnics are the four important higher study options for the mass. The disparity post secondary level is very critical in Malabar region. There is acute shortage of schools and courses after SSLC. Table 3 lists the district wise number of students who appeared for the SSLC examination March 2021, number of students who became eligible for higher education (EHS) and available higher secondary and vocational higher secondary seats for them. The number of available ITI and Polytechnic seats are also shown. The last column shows the difference between the number of students and the number of available seats.

Most of the students would prefer to join higher secondary schools after SSLC. In the academic year 2020-21, 417966 students were eligible for higher education in the state and only 3,06,150 seats are available considering the sanctioned strength of 50 students per batch. But due to high demands, the batch intake have been undergoing marginal increase making the number of students in a class up to 65. Again the pressure of crowded classrooms go to Malabar as the Table 3 clearly show.

There is a clear North - South or Malabar - Tirukochi divide in Kerala in the educational opportunities available even after 10th standard. Malabar is characterized by the seven districts that face shortage of seats and Tirukochi is characterized by the seven districts that face excess of seats.

District	SSLC Pass	HSS Seats	VHSS Seats	ITI Seats	Poly Seats	Total Available	Difference (I - C)
TVM	33891	24950	2800	5782	1275	34807	916
KLM	30547	22800	4025	4905	600	32330	1783
PTM	10341	12900	1925	766	880	16471	6130
ALP	21917	20800	1400	2183	660	25043	3126
KTM	19636	19150	1875	2588	770	24383	4747
IDK	11197	10350	1150	879	760	13139	1942
EKM	31491	26750	2325	2215	1050	32340	849
TSR	35158	27650	2400	2658	1620	34328	-830
PKD	38518	24150	1725	2468	480	28823	-9695
MPM	75554	41950	2325	1295	1180	46750	-28804
KKD	44430	29200	2175	3057	485	34917	-9513
WND	11518	7950	675	489	600	9714	-1804
KNR	34481	25350	1400	2311	750	29811	-4670
KSD	19287	12200	1325	1730	680	15935	-3352
Total	**417966**	**306150**	**27525**	**33326**	**11790**	**378791**	**-39175**

Table 3: The district wise number of students who passed the SSLC examination March - 2021, available seats in higher secondary, vocational higher secondary, ITI and Polytechnics and their total in each district. The last column givens the difference between the total number of seats available for higher studies and the number of students who passed SSLC exam and in the districts - giving the shortage of seats in each districts.

There are a number of self-financing institutions upon which students depend for their studies. Most of these collect huge sum of money from the students. Many of these institutions work in rented halls and rooms by registering the students in open school. A National Sample Survey report on Education in Kerala (NSS 71st Round Jan - Jun 2014) published by NSS division of Department of Economics and Statistics; when asked the students about the reasons for joining in private schools cited ‘Govt. Institution not available nearby’ as a major reason.

The data on the result of open school higher secondary of Kerala state named SCOLE Kerala shed light into the disparity at higher secondary level in Kerala. In 2020, a total of 50788 candidates had registered for 12th exam in Open stream of which 49245 appeared for the exam, only 21490 (42.3%) were eligible for higher studies. Among these, 81.2% students are from the seven Malabar districts. In 2021, a total of 49351 candidates registered for 12th exam in Open stream of which 47721 appeared for the exam, only 25292 (51.3%) were eligible for higher studies. There is a good improvement in the result and a total decrease in the number of students who depended on open schooling. Among the registered, 84.3% students are from the seven Malabar districts clearly showing the Malabar - Tirukochi divide - the number of students depending on Open school is decreasing in Tirukochi and increasing in Malabar region. Malappuram district accounts for 39.3% of the total registrations. There is a 4.7 fold increase in the number of students who achieved the highest A+ grade in all the subjects. In 2020, it was 132 students (108 from Malabar) whereas in 2021 it is 621 (491 from Malabar). The data shows that a number of studious students enrol in open school for their higher secondary education because of lack of opportunities in regular mode.

District	**HSS (at least one batch <50 Students)**	**HSS (av. of all batches <50)**	**Students Per Batch**
TVM	7	4	55
KLM	20	10	54
PTM	54	48	44
ALP	27	18	52
KTM	36	31	52
IDK	28	22	49
EKM	30	20	53
TSR	12	7	54
PKD	9	6	58
MPM	1	0	60
KKD	2	1	60
WND	2	0	60
KNR	11	7	58
KSD	7	4	58
	246	**178**	

Table 4: The district wise data of higher secondary schools with less number of students. Second column: number of schools in which at least one batch have less than 50 students, Third column: number of schools in which the average number of students per batch is less than 50.

The higher secondary schools are too much crowded in general in the Malabar region whereas many schools in the Tirukochi region work with nominal number of students. The Table 4 shows the number of schools in each district with less students. Second column shows the number of schools in which at least one batch do not have the statutory strength of 50. Third column shows the number of schools with the average number of students in a batch is less than 50 (batches of science, humanities or commerce courses). In certain places, children do not prefer certain courses, therefore that particular course may be left unfilled where as other courses have enough students. But if there are more batches in a school than required, in such schools in general the average number of students will be less than the intake capacity. To differentiate these two contexts, the second column and third column are separately given. It can be seen that 82.1% of the former and 86% of the latter cases are in the Tirukochi region. Another important indicator to see the disparity is the district average of number of students per batch. Malabar districts especially Palakkad, Malappuram and Kozhikode have an average of 60 per students per batch. Given that Palakkad, Malappuram and Kozhikode districts are the most populous districts with highest number of higher secondary batches, there are more children suffering with crowded classrooms.

Arts and Science Colleges

In a country like India where numerous communities with several inhibitions strive to come up, these arts and science colleges open door to liberation through education to several thousands every year. Arts and Science Colleges are the institutions of higher learning to the common mass.

District	HSS EHS	HSS FullA+	UG Seats	UG Per 1000 EHS
TVM	28405	4182	9297	327
KLM	25404	3794	6830	269
PTM	9986	1074	4541	455
ALP	19779	2375	6147	311
KTM	19200	3180	10956	571
IDK	9762	1396	3229	331
EKM	30616	5245	10879	355
TSR	31723	5276	10153	320
PKD	29535	3442	5642	191
MPM	61391	6988	6776	110
KKD	38011	5478	6208	163
WND	8510	917	2238	263
KNR	28394	4069	5439	192
KSD	12576	1289	2082	166

Total	**353292**	**48705**	**90417**	**256**

Table 5: The district wise data of number of students eligible for higher studies in the higher secondary examination 2021 (column 2), the number of students who scored the top A+ grade in all the subjects (column 3), number of available UG degree seats (column 4) and the number of seats available per 1000 eligible students (column 5).

A survey on higher education policy of the governments over the years and consequent efforts to ensure equity and the role of private managements in providing free education can be seen in Mathew, A (2019). But the kind of disparity in Kerala that is seen from school level through higher secondary and technical educations is continued into higher education as well. In the year 2021, a total of 353292 students were eligible for higher education in the higher secondary examination of Kerala of which 210140 were from Malabar and 143152 were from Tirukochi. But Malabar has only 38538 under graduate seats in publicly funded arts and science colleges - 124 seats per 1000 eligible students whereas Tirukochi has 51879 UG seats - 362 seats per 1000 students.

District wise data of available under graduate degree seats available in the publicly funded arts and science colleges in Kerala is shown in Table 5. Number of UG seats available per 1000 eligible students is lower for all the Malabar districts except Thrissur. Malappuram district is in the most pathetic condition in terms of higher education opportunities with a mere 110 seats per 1000 eligible students where as Kottayam district stands on top with 571 UG seats available per 1000 eligible students. The severity of scarcity of seats in Malappuram is so deep that the of students who scored the highest A+ grade in all the subjects is higher than the total available UG seats as shown in Table 5.

SUMMARY

Education is the only option for the disadvantaged communities to overcome their backwardness. Kerala is known for its high expenditure on education. Unfortunately the expenditure is not carried out in a judicious manner resulting in huge regional disparity.

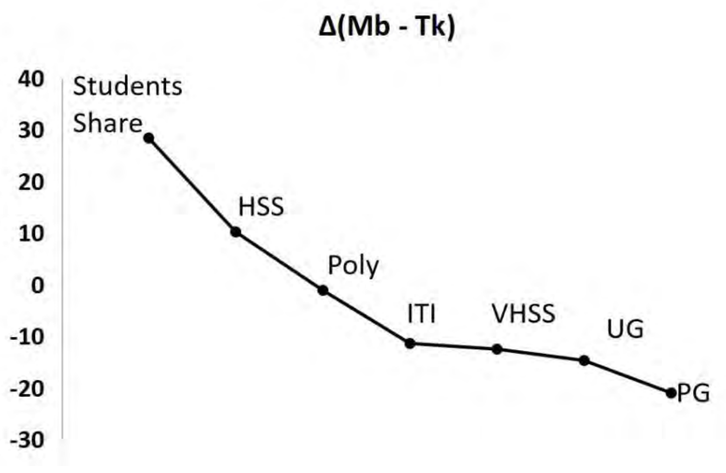

Figure 4: Divergence in educational opportunities between Tirukochi (Tk) andMalabar (Mb) at various levels in units of percentage (vertical axis). The labels correspond to - student share in classes 1-10 (Share), the share of seats in Higher Secondary Schools (HSS), Polytechnic

Colleges (Poly), Industrial Training Institutes (ITI), Vocational Higher Secondary Schools (VHSS), Undergraduate courses in Arts and science colleges (UG) and Postgraduate courses in arts and science college (PG)

There is clear north - south disparity within the state in the case of educational opportunities right from school education upwards as the present study has clearly established. The situation is clearly depicted in Figure 4. The figure gives the divergence between Tirukochi and Malabar in the proportion of available educational opportunities. The first value is the difference in student share. All the other values are the differences in seat share in the two regions. As the educational level goes up, the opportunities per eligible student in Malabar decreases and Tirukochi increases causing the divergence.

The number of students registered in Open School is in fact an indicator of the drop out that is forced upon students by the system after 10th class. Such *forced* drop out is disproportionately higher in Malabar region. After the dropping out of several students in the higher secondary level, even the remaining students do not have the proportionate opportunity in the higher education secotr as the present study clearly showed.

A National Sample Survey report on Education in Kerala (NSS 71st Round Jan - Jun 2014) published by NSS division of Department of Economics and Statistics presented interesting results on the enrolment of people in the age group 5 - 29 years in any educational institution. The report shows high enrollments in the districts in Tirukochi; but the top district in enrolment is Palakkad with 72.3% enrolment followed by Malappuram with 71.8% both from Malabar. Ironically, the highest enrolled but non-attending candidates also come from Palakkad district (9%). Malappuram and Wayanad showed high non-attendances (more than 4%). This is another indicator of lack of enough educational opportunities in these districts.

The problem of higher secondary education in Malabar is too severe. In the academic year 2021-22, the admissions to class 11 via centralized allotment process started on 23rd of September, 2021. After two allotments the first supplementary allotment results were published on 5th November. During 12th - 18th November 2021, an NGO named Malabar Education Movement carried out a survey in Malabar region to see the status of admission in the region. The classes for the 11th class students started on 15th of November. Out of the 529 respondents who applied for the admission, 78.4% didn't get a seat to any course in any school. Of them, 53 had an A+ grade in all the subjects in their 10th class.

Similar is the case of higher education as well. The fact that Malabar is very much neglected is not mere a historical fact. There were only 51 arts and science colleges at the time of formation of present day Kerala. Right now there are 238+ colleges together in government and aided sector. Moreover, new courses were added even in older colleges. In 2020, a total of 166 public funded courses (39 UG, 96 PG and 31 Integrated courses) were allocated into the arts and science colleges in Kerala. But only 19 UG, 48 PG and 13 Integrated courses were allocated to Malabar region.

CONCLUSIONS

The study showed that at all levels of education, there is clear disparity between the southern Tirukochi and the northern Malabar region of Kerala. Given that 35.8% of students in class 1 - 10 are in Tirukochi and 64.2% in Malabar region, all the educational opportunities and resources has to be redistributed among the regions in a very judicious manner to ensure equity in education within the state of Kerala.

Crowded schools need to be split up to ensure equity in terms of quality education and also uneconomic schools has to be judiciously shut down to stop wastage of public money. As 87.2% crowded schools are in Malabar, that is the region that is affected very much. 87.3% of uneconomic (which lack students) schools are in Tirukochi which means there is a lot of wastage of public money there.

Out of 41 educational districts in Kerala, only 19 are in Malabar and 22 in Tirukochi where as the student population is 64.2% and 35.8% respectively. If educational districts were formed in everywhere in Kerala according to the student ratio in Pathanamthitta and Alappuzha districts, Malappuram district alone would have 19 educational districts whereas right now there are only 4.

In the higher secondary level, 50 is the maximum capacity of a class according to the norms of the state government. But every year, a 20 to 30 percent marginal increase of seat capacity is implemented making the capacity 60 to 65. Once admissions are over in the higher secondary, vocational higher secondary, ITI and Polytechnics, the remaining students in the higher secondary schools give the clear idea about the number of students in a batch. It is 58.4 students in a higher secondary class for the last academic year (2020 - 2021) in Malabar and 51.9 in Tirukochi region, a significant difference.

In the undergraduate degree courses in Kerala, only 124 seats are available in Malabar per 1000 eligible students that has significantly affected education of backward communities, differently abled persons, and girls in the region. But Tirukochi region has 362 seats available for 1000 students. There are various other opportunities like Engineering, Medical, Paramedical and other courses which are not considered here as the scope of the present study is limited to the educational opportunities of the masses.

Serious thought has to be given to address the prevailing disparity within the state of Kerala. There has to be a scientific method while opening new institutions and allocating new courses else, such courses and institutions always go to people with more proximity to power centers. Using modern technology like artificial intelligence enabled automated systems, it would be very easy to have a permanent monitoring system for the purpose of delivering equity and quality. Such a system would greatly help in reducing wastage of public money as well as in ensuring optimum opportunities to everyone thereby ensuring equity.

The speculated reasons for the existing disparity are listed below:

1. There seems to be a bias inherent to the system because of two main reasons; one, the capital of Kerala is located in the southern most city called Thiruvananthapuram making it inaccessible to the people of the northern districts and two, most of the officials in executive and teachers are from the Tirukochi region which may lead to bias in many situations resulting in an over all bias in favour of Tirukochi region.

2. Even though the education ministers were from Malabar region most of the times, when it comes to allocation of new courses and colleges, there is a huge disparity in the allocations.

3. Regarding higher secondary education, most of the teachers in the government owned schools are from the Tirukochi region, they would prefer more batches in their neighbourhood.

4. There exist an order that pause threat of teacher posts being abolished if the number of students in a batch is less than 50 - this rule is applicable to those batches that came after 2014 only. These batches were mostly given to solve the seat scarcity in Malabar region. So The government aided schools in Malabar region are not in favour of new batches coming into the

region.

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SOCIOSCIENTIFIC ISSUES AND SCIENCE EDUCATION

Vishal Kumar[1, a, !], Sanjiv Kumar Choudhary[1, a, #]

[1]Birla institute of Technology and Science, Pilani

[a]He/his/him

[!]p20200030@pilani.bits-pilani.ac.in, [#]chskumar@pilani.bits-pilan.ac.in

Achieving scientific literacy has been accepted as one of the most significant aims of science education. Awareness about socioscientific issues has been attributed to the achievement of scientific literacy in science education. Socioscientific issues act as a context for discussion, debate and argumentation in the classroom which leads to better understanding of the issues by students and gives them a chance to scrutinize implementation of scientific innovations in social context and understand their interrelationships. The socioscientific issues aligning with the science concepts which have significance in terms of evaluation and are considered 'important' in the curriculum have only been researched. The community/context specific issues which are personally relevant to the students and teachers have not been explored. This study proposes to look into the teachers' knowledge and attitudes, and students' perceptions towards those socioscientific issues which are personally relevant to them through qualitative methods. As textbooks are one of the major teaching tools in the Indian context, it is important to scrutinize how such issues are represented and how students and teachers can be engaged in teaching-learning of socioscientific issues . This study proposes a detailed analysis of NCERT science textbooks (3rd to 10th standard) and implementation of lesson plans based on context specific socioscientific issues.

INTRODUCTION

Indian constitution guarantees Right to Elementary Education (RTE, 2009) to every child until the age of 14. Science education starts from class 3 itself (Environmental Science) and is mandatory till 10th class. Policy documents in the past have emphasized the need of cultivating scientific temper, critical thinking and scientific literacy among students and have mentioned these as the significant objectives of science education. However,the curriculum of science textbooks is too laden with information and gives little or no scope for students to discuss social and daily life problems. Hence, the curriculum of science education needs to be designed in such a way that it enables students to think critically, argue and make scientific decisions in daily life at personal and societal level. Scientific literacy is considered to be one of the significant goals of science education worldwide which enables students to place science and technology in a social context and scrutinize it.

LITERATURE REVIEW

Scientific Literacy: Meaning and significance for science education

The term scientific literacy has many synonyms. Different words have been used for this concept in different contexts. Scientific literacy as a term is widely accepted in the USA, Scientific culture in Europe, Public understanding of science is exclusive to England (Roberts,2007; Solomon,2005). James Bryant Conant (1952) is considered to be the proponent of the term 'Scientific literacy' (Bybee, 1997). Pella et al (1966) stated that there are six defining elements to it: 'understanding about the relation of science and society, ethics involved in pursuit of science, nature of science, conceptual knowledge of scientific concepts, relationship of science and technology, and the place of science in the humanities'. In the Indian context, National Curriculum Framework NCF (2000) also mentioned the need for inculcation of scientific literacy and defined it as "understanding of nature of Science, application of scientific concepts, capacity to understand values that underlie science, willingness to understand and appreciate the joint enterprise of science and society, ability to develop rich and satisfactory views of the universe and development of skills required in everyday life". This definition goes beyond just the conceptual knowledge of concepts and calls for the use of this knowledge for making everyday decisions. Hoolbrook and Rannikmae (2009) have put forward a detailed relevance based definition of scientific literacy for science education, "Developing an ability, to creatively utilize appropriate evidence-based scientific knowledge and skills, particularly with relevance for everyday life and a career, in solving personally challenging yet meaningful scientific problems as well as making, responsible socio-scientific decisions". Here again we can see that emphasis has been placed on use of scientific knowledge/content for daily life decision making. That means scientific literacy goes beyond the science classroom walls because it is not just about knowing the scientific facts. Scientific content knowledge has to translate into meaningfully deliberate scientifically informed daily life decision making. Sadler (2004) stated that scientific literacy has been accepted as one of the significant goals of science education. It is well documented that socioscientific issues can play an important role in enhancing scientific literacy. Hence, whenever there is discussion of Scientific literacy, understanding about socioscientific issues has been placed in the center (see Driver et al.2000; Kolsto et al., 2006; Pedretti & Hodson, 1995; Zeidler & Keefer, 2003). In 2009, in Program for International Student Assessment (PISA) rankings, Indian students ranked 73 out of 74 in scientific literacy. Since then, India has not participated in this assessment.

Socioscientific issues: Meaning and relevance for science education

As science and society evolve together and have implications for each other, some unique issues have emerged because of their interaction (Sadler & Zeidler, 2003). There are many such issues and to name some of them climate change, nuclear energy, surrogacy, effects of pesticides on health, etc. Socioscientific issues are complex in nature and because of their social and scientific implications, they are controversial as well and may not have a simple solution and require ethical and moral considerations (Sadler and Zeidler, 2003; Eggert and Bogeholz ,2009). Ratcliffe and Grace (2003) have also mentioned the characteristics of Socioscientific issues. According to them, these issues have a basis in science, involve forming opinions and making personal and social choices, and are frequently reported in the media, have incomplete scientific evidence and incomplete reporting, have local, national and global dimensions, involve cost benefit analysis, consideration of sustainability and ethical reasoning. National Curriculum Framework (2005) mentions six validity criteria for science education curriculum, in which the environmental validity states that "Science be placed in the wider context of the learner's environment, local and global, enabling him/her to appreciate the issues at the interface of science, technology and society, and equipping him/her with the requisite knowledge and skills to enter the world of work". Here we can see the indication of placing scientific concept knowledge in the broader context of society and also to understand the implications of science on society and vice versa. Environmental issues, safety and health, resources and energy, ecological system, biotechnology and new materials are some of the major topics in this domain and should be emphasized upon in the science education curriculum as these topics have a greater relevance for the society (Wan, 2019). In Indian context, the importance of issues can vary from one child to another as they may be brought up in different conditions. First, let us take a look at how socioscientific issues have been studied in the educational domain.

Teacher knowledge and attitude towards socioscientific issues

Teachers' knowledge and beliefs about a particular issue plays an important role in the pedagogic reconstruction of knowledge about that issue in the classroom. Teachers tend to have a moral influence on the students because of their beliefs, that is why their beliefs need to be examined (Bukor, 2011). Wilkins (2008) talks about a theoretical model to understand the background of a teacher. This model considers the aspects, content knowledge and attitude to be the most important. Content knowledge has been traditionally connected with the kind of degree a teacher possesses, i.e., if a teacher holds a degree in a discipline, it is automatically considered as an indication for possession of content knowledge of that subject. But Schulman (1986) coined the term ‘Pedagogical content Knowledge’ which is also referred to as ‘content knowledge for teaching’. It is important to understand, especially in science education, that the teacher needs to possess proper scientific knowledge about the issue and knowledge of pedagogic methods before teaching it. Teachers’ attitude towards their subject or the topic has been attributed to the student's success (Abe, 2013). That means if the teacher thinks that the topic is important for the students, it influences their pedagogy in a positive way. Levinson and Turner (2001) stated that teachers believed it was important to integrate social and ethical considerations in science teaching but most of them from the same study were also found to be given more importance to the science content while teaching. Teachers’ personal attitude and knowledge about socioscientific issues have been studied in various contexts and multiple times. Liu et al. (2015) reported that many teachers did not feel themselves equipped with enough knowledge to teach climate change. A lot of studies have been done on controversial issues such as evolution, surrogacy, gene therapy etc. Mainly those issues have been explored which have either been traditionally given importance in the science curriculum or which are relevant for the larger contexts in society. One important gap till now in research is that the issues which are of personal relevance to the teachers and the communities they belong to have not been addressed. It will be interesting to look into the attitude and knowledge of teachers towards those issues which involve themself as a stakeholder. As we know that ethical and moral considerations play an important role in socio scientific reasoning, it will be interesting to see how teachers argue about the issues in which they are stakeholders, whether they consider other perspectives also or not.

Students’ understanding about concepts of science and socioscientific issues

Children make sense of their surroundings on their own through personal experiences embedded in their immediate environment. “Piaget suggests that children search for meaning as they interact with the world around them (see Eggen and Kauchak, 2004, p.281) and use such experiences to test and modify existing schemas” (as cited by Thompson & Logue, 2006). But this has negative implications for science education and teaching. As children have made sense of the concepts around them through their experiences, it becomes hard for educators to challenge those insights. Students’ conceptions about scientific concepts which have dominant space in textbooks and assessments only have been explored but the concepts/issues which are relevant to the students and have social and scientific implications in their lives have been ignored. If we talk about socioscientific issues and student conceptions, again this pattern can be seen that issues such as climate change, evolution, stem cell research have been overly explored and context specific, community specific relevant issues have been overlooked. Frick et al. (1995) conducted a study in the USA, which looked at the knowledge and perception of rural and urban students on agriculture and other concerned issues. A significant finding from this study was that “Rural High School Student respondents had significantly higher knowledge concept scores than Urban Inner-City High School respondents in all of the seven areas. However, Rural High School Student respondent perception concept scores were found to be significantly higher in only the animal and plant areas.” This exemplifies that when issues closer to the day to day life of students are explored, students tend to show higher level of understanding rather than in the issues which have been emphasized in the textbooks.

Science textbooks and Socioscientific issues

Textbooks are one of the most significant teaching learning materials that are used most of the time especially in the Indian context. “In many Indian science classrooms, the NCERT science textbooks are the only instructional tools available; therefore, the quality of these state prescribed science textbooks should be a major policy concern (Kumar, 1988).” (as cited by Koul, 1997). Teachers depend a lot on the textbook and hence, the discussions in the classroom are guided by the textbook. Morris (2014) has examined the science textbooks in England in terms of which socioscientific issues are given how much space in textbooks. He found that genetic technology and climate change were the two most prominent issues (50% and 21% respectively). The space percentage for these two socioscientific issues was higher than the others. Issues related to agriculture were given four pages in the textbook and 17% space of the whole unit. Such studies have not been done in the Indian context. Raveendran & Chunawala (2015) in the feminist critique of NCERT textbook chapter on reproductive health report, “The textbook’s latent function seems to be that of serving the state agenda of reproductive control of its citizens, particularly women, through the use of technology as manifested by its celebration of the population control policy as well as by discussing fertility-enhancing technologies, and limiting the scope to question its role in reinforcing patriarchal notions of genetic parentage.” This exemplifies that the state can use the textbooks in shaping citizens’ minds. And especially, issues of high political relevance can be portrayed in a manner which suits the agenda of the state.

RESEARCH GAPS

As mentioned in the above discussion, almost all the educational policy documents in India and around the globe consider scientific literacy as one of the most significant goals of science education. It has also been well documented that using socioscientific issues as a context in science classrooms leads to better understanding of those issues by the students and it also helps them in achieving better levels of scientific literacy. In Indian context, a major study on the correlation between scientific literacy and awareness of socioscientific issues by students has been well documented by Sunita Singh (Scientific literacy and awareness of socio scientific issues among higher secondary students, 2018). This study found that 41.44% higher secondary students were scientifically literate and only 37.77% were aware of socioscientific issues. This reflects that socioscientific issues have not been given their just space and attention in the science classrooms. One limitation of this study is that the nature of data is quantitative. Hence, for a comprehensive understanding qualitative study is needed. Now that it is clear that socioscientific issues can play a major role in enhancing scientific literacy, its implementation as a context in the classroom and impact has not been explored in the Indian context. All the studies done regarding such issues in European and American context have looked into issues which are relevant for the society at the broader level. Issues such as evolution, use of animals for medical testing and many other issues in biology education have been already explored multiple times. This study proposes to look into the students' arguments, knowledge and beliefs about such issues which are personally relevant to them and their community. Because there is a strong moral and ethical dilemma regarding these issues, it would be interesting to see whether they are willing to participate in a sociopolitical action for this issue, which has been proposed as the next step after achieving scientific literacy and consolidating it (Hodson,2003). Similarly, in the case of teachers as well, this study proposes to look into their attitude, belief and knowledge about these socioscientific issues in which they are stakeholders themselves. With the literature survey done so far, it is felt necessary that the use of socioscientific issues in the classrooms be explored in detail to understand its implications for pedagogy, textbooks and teacher preparation.

CONCLUSIONS

Contextualisation of science concepts helps students in understanding concepts better as they get a chance to connect the local context with the global understanding. Similarly, socioscientific issues which are specific to the students' context can help in developing their scientific literacy and make them aware about the problems within their communities and this also opens a door for contemplation about the possible solutions. Hence, there is a need to look into the perceptions and understanding of science teachers, students from a specific community about socioscientific issues emerging from their own context and how such issues can be implemented or used in the science classrooms.

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THE VULGAR AND THE PRISTINE: EXPLORING THE BARRIERS IN USING THE VERNACULAR WHILE TALKING ABOUT SEXUALITY IN BIOLOGY CLASSROOMS.

Panchami Jose

Homi Bhabha Center for Science Education, Mumbai, Maharashtra, India.

panchami@hbcse.tifr.res.in

This paper examines how embarrassment associated with sexual terms challenges biology teachers when teaching topics related to body and sexual health. The paper is based on classroom observations and subsequent discussions with teachers in three schools in Wayanad, Keralam. In the classroom, it was observed that the teachers were more comfortable using English words than equivalent Malayalam words. The paper explores the reasons that forbid the teacher to use Malayalam while discussing sexuality.

INTRODUCTION

Talking about sex and body is difficult for most of us because of its private and intimate nature. Further, the cultural stigma attached to them makes discussions unclean and vulgar. When shame is seen as a desirable trait in society, talking about such topics makes one "shameless". Sex, sexuality and body become so shameful that to embarrass a person, one only needs to invoke them in conversations. Riezler (1943) talks about different functions of shame in the matter of sex. Shame "protects" children and young adults during their sexual maturation. It makes sex private by concealing the talk around it. More shame is associated with the observation than the action itself. So talking, thinking and listening about sex become more annoying than the act of sex. Like the observer and exhibitionists, the one who talks and the listener also become shameless. Sex and desires are removed from the public discourse, partially or entirely, due to their threatening nature to society (Mollon, 2005). Strict censorship of direct sexual words has led to the evolution of many indirect references. Language and sexual morality are intertwined so that one becomes an indicator of the other. Explicit and crudely sexual language marks a degenerate group, whereas its absence is a marker of a sophisticated crowd.

Talking about sexual intercourse and body, particularly to young people, becomes an ethical question for teachers since those discussions are forbidden (Mbananga, 2004). The conflict between the content and the personal/cultural values leaves many teachers uncomfortable (Ahmed et al., 2009). The paradigm shift in the socialising pattern of teachers and students complicates the discussion of such taboo topics. Teachers who have not been taught the same way as they are now expected to teach are left with anxiety. Teachers are frightened of encouraging sexual activity among students through these discussions, opposition from parents and being viewed as shameless (Francis, 2012). The socio-cultural and historical construction of 'childhood innocence' discourse, where any sexual knowledge can harm their 'innocence' (Bhana, 2009), brings more dilemmas while teaching and forces them to think of students as 'non-sexual beings' (Allen, 2007). Teachers' confidence while teaching adolescent children depends not only on their sexuality pedagogical and content knowledge but also on their personal and cultural values and the perceived need for such discussions. Simayi & Webb (2019) studied the taboo restrictions in the language and lexicon while teaching reproduction in rural Eastern Cape schools. They report that as community members who value tradition, teachers avoid using reproductive terminologies as they are offensive in their culture. Many reproductive terminologies have become derogatory and sexist slur words across cultures and languages (Borah et al., 2020). In many cultures, direct references to sexual acts and sexual organs are seen as insensitive and offensive, which restricts the teachers from using those terminologies in the native language (Doidge & Lelliotte, 2017; Helleve et al., 2009). To navigate these difficulties and struggles, teachers feel that one needs “guts” to teach about sexuality (Francis & DePalma, 2015).

BACKGROUND OF THE STUDY

The paper draws on classroom observations of twelfth standard biology lessons and the subsequent discussions with the teacher. Three Biology teachers, consisting of two men and one woman, allowed me to observe their classes on the chapters - Human Reproduction and Reproductive Health over two months. The schools in this study are located in Wayanad district of Kerala. The schools include one government and two government-aided schools. Admission to the 11th standard in Kerala is through the single window system within each district. The schools with a history of excellent performance attract more academic achievers, creating a hierarchy among the schools. The two observed schools had students who scored less in the 10th board exams. The classes in these schools are predominantly bilingual. Many students have completed 10th in Malayalam medium, and a sudden shift to English makes learning difficult. One year of online sessions also made adapting the medium to English more difficult. The limited number of teaching hours due to the pandemic made the teachers emphasise more on the concept rather than the medium of instruction. So teachers use Malayalam as the primary communication medium since students find it very difficult to understand and write in English. Although the textbooks are in English, students will be given marks even if the answers are written in Malayalam.

During the classroom observations, I noticed that all three teachers, even though they were talking in Malayalam, used English vocabulary when there were references to sexual acts and genitals. I was doubtful about the students' knowledge of these English terms as they showed difficulties with other words in English. I explored this more during the conversation with teachers, where they talked about their inhibitions in using Malayalam terms in the class. These short conversations after the class with the teachers were audio recorded. Some of the insights from these conversations are discussed in this paper.

There is no attempt at generalisations in this paper. Instead, these are some observations made from the classroom and discussions with the three biology teachers in the locale within Keralam.

DISCUSSION

The vulgar vernacular

How the word referring to sex or sexual organs entered the public sphere of English speaking audience, for instance, the word "fuck" (Horvat, 2016), has no parallel in Malayalam. Each language represents a particular culture and imbibes the taboos which are part of the culture. There are no acceptable non-obscene words in Malayalam to refer vaginal penetration or any other sexual acts. The commonly used words to refer to any sexual act are "lyngika bhandam" or "sambogam" which translates to sexual relationships. Any other slang words to refer to sexual acts are forbidden from the public spaces, and people who use them are deemed profane.

Withdrawing/barring talks on sexuality from the public discourse induce shame in the individual. Hence there should be a counterbalance that can infiltrate current social norms on sexuality to remove the shame attached to sex (Pancake, 2012).

The word "arthavam" (meaning menstruation) was absent from the formal spaces until a few years ago. The debates over the entry of women into Sabarimala (Kumari, 2019) brought the word Arthavam into the public space, removing the taboo aura around it. A teacher has pointed this out,

1 S2: It was challenging to say menstruation earlier. Now it is not that difficult. Previously, students did not use the word menstruation; they talked about it indirectly. They refer to menstruation as the time of blood loss. Now it has changed completely. They talk about their menstrual dates and home rituals.

The frequency and popularity of the word "arthavam" have reduced the taboo and made it more acceptable in everyday language. The word's acceptability has enabled teachers and students to discuss menstruation effectively.

It's easy to talk sex in English

In the most popular sexuality education youtube channels in Malayalam, 'Maya's amma', 'Asiavilla' and many news debates, it can be observed that the speaker switches the language to English when they have to mention sexual acts and genitals. One reason is the reliance on Western literature to teach and talk about sex. This can also be seen in the recent safe touch programs called 'good touch bad touch', which uses English vocabulary and has drawn heavily from the western teaching model. The lack of an appropriate Malayalam lexicon or knowledge makes it challenging to communicate in Malayalam. The use of English for sexual references by the media can also be seen as an attempt to filter the audience, alienating the non-English speaking crowd and the children. While focussing on the English speaking crowd, we assume a 'descent-progressive' community where sex is less taboo. The dependence on English also limits the sexuality education platforms to a smaller crowd, giving it an elite nature. A teacher mentioned this,

2 S1: For academically better students, the language will not be an issue; however, the low performing students will not be able to understand the English terms, especially these sorts of words.

The "dirty" colloquial

3 I: In Malayalam, colloquial words are used more than formal words in the context of sex. These colloquial words cannot be used inside the classroom. For instance, for penis, we use 'lingam' in the standard language, but in colloquial language, there are other words. The issue is that we cannot use it in the class as they are used as curse words. I use the standard Malayalam words and English both together. The students will not be able to understand the formal Malayalam words as they use only the colloquial ones. So it is no different from English.

The Sanskritised Malayalam words, the only ones allowed in the public spheres, are less used in the private spaces. People are more familiar with the colloquial usage of these words; however, these sound offensive when used in formal spaces. The colloquial terms have the characteristics of the class, caste and the location of the speaking crowd. Most of these sexual references are barred from the Middle class-upper caste Malayali's speech, even in the private spaces. For instance, a penis is introduced to a growing child as "nanam" meaning shame and does not have a specific word for it. The disapproval of the colloquial words is also the disapproval of the people who speak them.

The discomfort in using the colloquial words is more for the female teacher. The less familiarity of these words owes to the societal expectation of women to be sexually ignorant and innocent. A male teacher had fewer inhibitions to talking in colloquial language,

4 S2: The next is the colloquially used words. They will not use it while talking to me. They talk about it indirectly by saying 'it" that' and so on. I do not use colloquial language unless students use them in questions. If I use the colloquial terms, each student perceives differently.

When everything becomes a slur

5 S2: Boys use the word "samanam" to refer to the penis. If I use the word Samanam in the class, that will bring mixed feelings among students coming from different locations. I don't use them because, in many homes, fathers abuse wives and children using these unparliamentary words.

Many swearing words in Malayalam, like other languages, are directed at the gender, sexuality and genitals of the person. The swearing words reflect the societal norms around gender and sexuality and the people's repressed desires and fantasies. It becomes the only outlet for the people to talk about the things that are forbidden. These swear tones make these acts and behaviour more and more offensive and immoral. For instance, calling a woman bitch not only does the purpose of insulting that person but also characterise this sexual preference as immoral. These narratives of danger, immorality and self-destruction are used to control and police the sexuality of the people. These controls and fears have influenced the culture, vocabulary and emotions regarding sexuality for generations.

Similarly, the words to refer to the genitals make those body parts offensive, shameful and private. Most of these profane words are directed at the women (and other oppressed) and have misogynist origins. Hence, the stronger emotion these words evoke forbids the teacher to use them in the class.

Listen, but not visualise

6 S2: We use English terminology to teach anatomy. I tell them the Malayalam meaning of these words. For instance, I tell them that vagina is the "yoni ", the uterus is “garbapathram”, and explains "andasheyam", "andavahinikuzhal", and so on. I keep in mind that I tell the Malayalam words only once; otherwise, it will lead to visualisation.

As most Malayalam words for genitals, even the formal medicalised terms such as "yoni" and "lingam" are hyper-erotised in erotica that students are following. This makes these words frightening for teachers as they can evoke images in students' minds, which can inform their thinking. In general, much emphasis is given to improving the students' visualisation in the teaching-learning process; however, when it comes to topics related to sexuality, teachers try to hinder their visualisation. This is achieved by using a language that is less familiar to the students. Teachers are aware that students cannot make much sense of the meaning of these English terms and hence will not be able to create a mental image of what the teacher is talking about. The official nature and the uneasiness the English brings to the students also change the classroom into a formal and academic space.

English helps the speaker to distance oneself from the speech and feel less vulnerable. A teacher mentions,

7 S2: The students won't be able to understand the English terms. They write the English terms in Malayalam. They write 'va' 'gi' 'na' in Malayalam. During exam evaluation, we understand that they can't spell and write these words in English, so they write in the Malayalam script. Very rarely I have seen students using Malayalam terms. Many girls find it difficult to write 'yoni' as they think that it is related to me. 'Vagina' is someone else's. I have noticed that they are more confident to use 'vagina' than 'yoni' while talking.

Thinking, seeing and touching one's own body, especially the genitals is scary for many, especially women, because of the social conditioning. The body is a source of shame in our society that requires it to be hidden and not talked about. The alienation that English as a formal and foreign language provides from one's body makes it easier to communicate with. The teachers also do not want the students to think about their bodies as that can be shameful. Discussion on sexuality is an uncertain realm which can go into rugged terrains and evoke different emotions (pleasant and unpleasant) among students. English helps to talk about the body objectively without associating any emotions.

English comes with power

Teachers feel that when they use the Malayalam words, it can become 'loose talk'. The teacher's fear of losing power and control of the class while teaching sexuality education is documented in the literature (Khan et al., 2020). Teachers perceive that the language is closely tied with their modesty. The fear of change in the power relation seems more threatening for teachers when they are discussing the issues related to reproductive health compared to other topics. Any talk about sexuality is disturbing and uncomfortable; it becomes more complicated when one is required to maintain a power hierarchy with the audience. This mostly comes from the fear of the unpredictable nature of the students' questions that can arise in an informal setting. A teacher says, "You can't imagine what kind of content they watch; once, a boy asked if it was okay to swallow it". As students are familiar and knowledgeable of many aspects of sex through porn, teachers feel vulnerable. The limitless nature of porn and its exposure can bring unpredictable and unacceptable questions to the class. Because of the uncertain nature of the questions, teachers do not feel confident and fear if they appear less knowledgeable than students. Also, responding to students' "culturally inappropriate" questions can come across as the teacher being shameless.

English, a foreign language, gives teachers an upper hand while communicating and helps keep the Adult-child distinction. English, which will convert the space into a formal one, helps the teacher regain power and feel less vulnerable.

CONCLUSION

The article has discussed some difficulties teachers face in using Malayalam terms while teaching Biology chapters on Human Reproduction and Reproductive health. The reasons for this are multifold. The fear of using Malayalam comes from the prevalent moral codes and the taboo associated with sexuality and genitals. English reduces the shame associated with the exact words as people who are perceived to be sexually liberal speak them. Hence Malayalam and English words with the same meaning are perceived differently by the same audience. Teachers shift to English to avoid students visualising and fantasising when they talk about sexuality. The non-familiarity and the formal status of English help the discussion to look decent and legit. Language alienation helps the students not think about their bodies and discuss these topics objectively. Many of the Malayalam words to talk about sex, both formal and colloquial, are used as abusive words. Since they evoke different emotions among the audience, teachers restrain from using them. This may hinder the students' understanding of reproductive health and make communicating challenging. So it is essential to normalise these Malayalam terms by using them in public. The taboos of these words can be removed if they are spoken aloud repeatedly in public spaces. Communication can be improved by breaking the formal-ness and the official nature of the space. Students understand what discussions, questions and lexicon are acceptable in a regular classroom with a defined teacher-student power hierarchy. Teachers mentioned that students feel free to ask more questions outside the classroom- in adolescent education and career guidance club "souhrida". This offers an informal environment for the students to express themselves more comfortable and negotiate power. More informal spaces need to be created to make the discussion around sexuality more comfortable for teachers and students. Recognising and acknowledging teachers' struggles and experiences of shame is crucial to designing and improving teaching training programmes.

A future study can examine how doctors and medical practitioners talk about the body with patients and other people. This study can explore how/if the medical training helped them navigate the shame associated with these words and the body parts. Identifying these features can help design teacher workshops and make the talk about sexuality and body more comfortable.

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TOWARDS AN EVIDENCE INFORMED POLICY-MAKING MODEL: DESIGN AND IMPLEMENTATION OF A TEACHER PROFESSIONAL DEVELOPMENT PROGRAM

Arjun Prasad[1,a,!], Sanjay Chandrasekharan[2,a,#], Sreejith Alathur[3,a,^] and KK Mashood[2,a,*]

[1]Kerala State Council for Science, Technology and Environment, Kerala, India

[2]Homi Bhabha Centre for Science Education, Tata Institute of Fundamental Research, Mumbai, India

[3]Indian Institute of Management Kozhikode, India

[a]he/him/his

[!]arjun.kscste@kerala.gov.in, [#]sanjay@hbcse.tifr.res.in , [^]asreejith@iimk.ac.in, [*]mashood@hbcse.tifr.res.in

We describe a first attempt towards formulating an evidence-based model to develop operational-level educational policies at the state level, based on a project that sought to implement some recommendations of the National Education Policy 2020. Radical framework changes such as NEP are difficult to implement, as they require operational-level policies that address the many hurdles faced by teachers on the ground. As a start in this direction, a unique tripartite collaboration between three key stakeholders - a national institution in science education research, a policy-making body of a state government, and practising teachers - was formed, to develop a gradualist curricular model, which allowed physics teachers to transition to computational modeling. Training modules illustrating the transition, from existing derivation modeling practices to computational and interdisciplinary modeling, were designed by this collaboration, and introduced to physics teachers across Kerala, through six teacher professional development (TPD) workshops. We discuss, from a policy-making framework, some of the major challenges in the implementation of this curriculum transition, as enunciated by teachers. Teacher responses indicate that they agreed with the required transition, but needed regular and highly focused TPD programs, to motivate and equip teachers to implement this radically different education model. For wider acceptance of the model, participants proposed extending similar programs to school teachers, and incorporating the modeling theme in the curriculum framework itself. The data from the TPD programs are currently being analyzed to frame better policy frameworks and operational strategies. We propose such tripartite partnerships as a nationally replicable collaborative framework to develop operational-level policies in education.

Keywords: NEP 2020, evidence-based policy-making, TPD programs, design-based research for policy-making

INTRODUCTION

Educational policies across the world, such as the Next Generation Science Standards (NGSS) in the US and the National Education Policy (NEP) 2020 in India, envisage radical changes in the nature of higher education, to adapt to fast-changing contemporary STEM practices (Chandrasekharan & Nersessian, 2015; Nersessian & Patton, 2009). Globally, there is a consensus that a transition is needed – from the existing curricular model where disciplines are taught in a compartmentalised manner, towards interdisciplinary training that integrates natural science and social science. This transition would allow the education system to facilitate and support contemporary STEM practice, where complex real-world problems such as climate change, sustainability, and pandemics are studied using highly interdisciplinary methods, and the resulting data is integrated using computational modeling (CM), to make predictions and build technologies. Education systems across the world are struggling to adapt to this systemic change. A key factor that does not feature much in discussions related to this struggle – particularly in the Indian context – is the required integration between policy, research and practice, and the need for design-based research to formulate operational-level policies that could facilitate this transition.

NEP 2020 is a national-level framework policy, outlining the general direction in which the country's education system should be heading. The ground-level implementation of this framework policy, and the design of operational-level policies to facilitate implementation, raises a host of challenges. The implementation process requires collaborative effort from multiple stakeholders involved in the process, and inputs from practising teachers. While policies such as NEP seek radical change, teachers have to begin from the existing curriculum and instructional framework (Cohen & Ball, 1990), and there is resistance towards such instructional changes. To address these, there is a growing trend to develop research-based policy-making processes (Tripney et al., 2014), drawing on scientific approaches, empirical studies, and research insights. Technological advancements have intensified this transition to evidence-based policy (EBP) and knowledge-aided governance in education (Tripney et al., 2014). In contrast to opinion-based policy, EBP builds on high quality research evidence gathered in a systematic and critical way (Lee & Davies, 2004). Pilot studies and case studies, done before extensive execution, are used as sources of evidence for policy making.

Here we present the evolution of such an effort to develop an evidence-based policy framework, to operationalize and implement some of the educational transformations envisaged by NEP 2020. Faculty members from the Homi Bhabha Centre for Science Education (HBCSE), in collaboration with an official from the Kerala State Council for Science, Technology and Environment (KSCSTE), first formulated a participatory framework, to promote computational modelling and interdisciplinary thinking at the undergraduate level. This framework then evolved further, into a tripartite structure incorporating the key third stakeholder in any educational transformation – practising teachers. Section 2 discusses the details of the stages in the formation of the tripartite framework, which resulted in the development of a state level seed model. As the first phase of this model, we designed and conducted a series of six 2-day teacher professional development (TPD) programs for undergraduate physics teachers in Kerala, where around 110 teachers participated (about 10 % of the UG physics teachers in the state). The details of the programs are discussed in section 3. We elicited teachers' thoughts and responses on the possible challenges and difficulties in implementing the objectives of the program. We discuss this data, and end with some future directions and concluding remarks.

RESEARCH, POLICY, PRACTICE - A TRIPARTITE FRAMEWORK

As discussed above, the goal was to formulate a framework to develop a seed model (Figure 1) at the state level, to operationalize the implementation of NEP 2020. The development of this framework started with a discussion between two HBCSE faculty and a member of KSCSTE. As one of HBCSE's mandates is to develop new curricular models in science and mathematics, its members took the lead in developing the research - academic dimension of the framework.

KSCSTE, as part of the science policy-framing body of the Government of Kerala, took the lead in the organizational and implementational dimension of the framework.

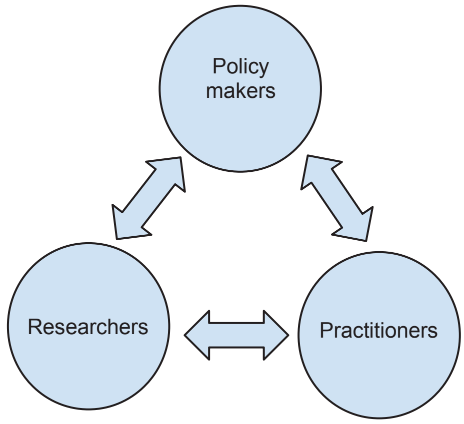

Figure 1: A schematic of the framework

The initial goal was to conceptualize a modest project, implementable within the constraints of available resources and manpower. A conceptual framework, based on modelling and model-based reasoning at its core, was developed at HBCSE, to help teachers move towards interdisciplinary teaching using CM methods. This design draws on insights from cognitive science, learning science, physics education research, philosophy of science, and computational modelling. Two graduate studies courses at HBCSE (Mashood & Chari, 2019; Mashood & Chandrasekharan, 2020-21), as well as papers and software (Homi Bhabha Centre for Science Education, n.d.) from the LSR group's research, contributed to this conceptual framework. Once modelling was conceptualised as the vehicle to achieve our objectives, we decided to focus on derivations in physics, as they are the final products of extensive mathematical model-building by scientists, and thus fit well with the modelling narrative (Nersessian, 1992; Knuuttila & Boon, 2011; Bokulich, 2017). They are also a core component of college level physics instruction, which enabled developing a training program relevant for practising teachers. As part of the design, the team interviewed and elicited the thinking processes of computational modelling experts (who were also teachers), to extend derivation models to computational models. Integrating these elements, a pedagogical framework was developed, connecting derivations and 'bridge' simulations that support teaching/learning. This structure served as the basis for developing TPD modules. In the next stage, practising teachers were actively involved in the design, to form the tripartite framework.

In collaboration with one of the interviewed modeler-teachers and another faculty member at a university in Kerala, we developed a set of modules, which were refined through several iterations. KSCSTE then provided a grant to conduct six workshops, and identified two state universities for the implementation of the TPD programs. Applications were invited from interested physics faculty members from colleges and university departments in Kerala, to participate in the training program. Due to COVID-19 regulations, the number of participants for each program was limited to 20. To follow a more decentralized approach, colleges under the two state universities were also identified to conduct half of the programs. Around 110 teachers participated in the six TPD programs. Figure 2 outlines a schematic of the operationalization of the project. All the workshops were highly interactive, and teachers' thoughts, suggestions, critiques and concerns were elicited, which we discuss next.

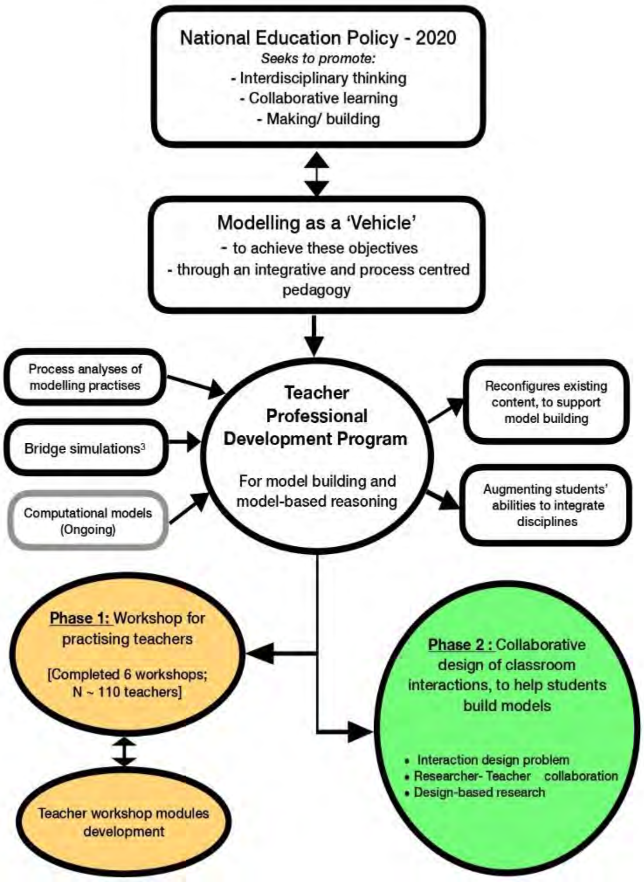

Figure 2: A schematic of the operationalisation of the project. From conceptualization to implmentation

METHODOLOGY, DATA COLLECTION AND ANALYSIS

Our methodology draws broadly on design-based research, wherein we first developed a promising intervention based on conceptual analysis and NEP requirements. This prototype was then implemented and improved iteratively. The initial training modules were first presented to a group of 5 physics teachers interested in introducing CM at the undergraduate level. The modules were revised based on their feedback, before presenting in the TPD programs. The feedback from the workshops conducted so far will be incorporated in future iterations. Both the pilot and subsequent workshops were video-recorded. Transcriptions of these recordings, along with written feedback from teachers, constitute the corpus of our data.
The workshops involved multiple interactive sessions on: a) deconstructing derivations as mathematical modelling activity d) comparing/ contrasting the analytical approach to solve equations with numerical methods c) use of interactive simulations to teach derivations d) extending the derivational approach to computational modelling and interdisciplinary thinking e) issues pertaining to technology adoption in classrooms. Through interviews and focus group discussions, the diverse challenges faced by teachers while adopting the technology based pedagogical framework were discussed and analyzed. The focus of the present paper is on the discussions that happened in the workshops, pertaining to the points mentioned below.

Teachers' response to the conceptual framework based on modeling

Teachers in principle agreed that adopting the modeling approach during derivation and problem-solving would help students understand the physics behind the problems, as it enables them to visualize the concepts better. They acknowledged that the sense-making aspect of doing physics, and the thought processes of physics, become evident in the model-based approach. This allows students to move away from conventional rote learning, towards imagination and thinking skills. In addition to these aspects, teachers appreciated that this way of teaching would help students get more involved in the subject and realize connections with real-world problems: *"I loved the way a problem was approached from different perspectives. Usually, we teach an equation to solve a problem, which is far from the reality. How students should think towards reality also seemed to be interesting".* Teachers also appreciated the potential of modeling existing derivations in the syllabus using new media: *"when taught through mathematical modeling, students will be able to visualize the concepts easily"*. This feedback suggests that modeling-based education have the potential to make classrooms more active and student-centric, equipping students to think, and also model real world problems.

Teachers' thoughts on policy changes needed to implement the design

Most teachers, though agreed in principle, were not convinced on incorporating and implementing the modeling approach under the existing curriculum. They suggested modifying the existing curriculum framework: *"if the (modeling) approach becomes part of the curriculum, teachers will be forced to learn and teach. In that way, it will reach the students."* According to them, including the modeling approach in the college curriculum would help in the wider acceptance of the methodology: *"the concept of mathematical modeling should be part of the curriculum… to reach the concept uniformly to all students..".* Suggestions were also made to incorporate an exclusive course on modeling in the curriculum. Many teachers insisted on more workshops, with training on similar interactive models, to help implement the modules in the classrooms: *"...even if only 30% of teachers are interested, if regular training can be provided to them, the rest of teachers will get motivated towards the new teaching approach."*

Teachers appreciated the workshop design, and indicated that it was different from most training sessions they have attended as part of their professional development, which lacked focus and relevance in augmenting their teaching. Many early-career teachers wanted hands-on training sessions focused on programming, to learn and build new interactive tools for teaching. *"Refresher courses should be designed in training teachers in that area…will be a good idea".* As teachers are required to attend mandatory professional development programs, most of which are about five days long, many teachers insisted on modifying the current format of the TPD program, to meet the stipulated guidelines of the respective governing bodies: *"a week long short term course (could) be designed in tune with the requirements of the Career Advancement Scheme of college teachers as per UGC regulations…".* Further, they also insisted on maintaining the continuity of training: *"require next level continuing program (for those) who attended the previous programs".* Suggestions were also made that the apex body involved in preparing the official training schedule of teachers should be convinced to incorporate the TPD program, to encourage wider participation by teachers. Also, teachers suggested introducing the modeling way of teaching from school level itself, as students conceive ideas in a subject very early in their career: *"I think the training based on modeling should begin from +2 level (school) itself."* Teachers argued that change in curriculum/ policy is required for the successful implementation of the approach, as the current curriculum offers limited academic freedom for teachers, and this restricts them from experimenting with novel ideas.

Teachers' concerns on implementing the workshop ideas in their classrooms

All changes proposed by new policies are perceived by teachers through the lens of their acquired knowledge, belief and practice. Supporting this view, many teachers initially found the proposal to incorporate the new approach within the existing curriculum difficult, due to time constraints: *"Does our curriculum allow us to show an experiment in more than one way? Do we have time?"*. Teachers were also concerned that there is less significance in teaching through modeling if the assessment pattern remains the same: *"students learn according to the way they are expected to write the exam."* A student taught concepts in physics in a modeling way would be assessed using the conventional pattern, where recall questions based on derivations form the major part, so: *"If it is made sure that new problems based on modeling approach will be asked (for exams), then teaching will be done in that way."* Many teachers believed that disparity in learning abilities of students in a classroom would hinder the implementation of the modeling based approach: *"....many students who score 90-95% marks at school level find it difficult to perceive things we teach in classrooms.... for many students it is like mugging up certain things and pass the examination, that's it."* However, other teachers opined that more clarity in learning new concepts, through the modeling approach, will motivate more students towards the subject.

Teachers' thoughts on technology adoption in the classroom

A session was conducted exclusively to understand teachers' views on the technology adoption required by the modules. Teachers expressed excitement in learning about the model-based learning approach's use of technological tools: *"learnware tools are really a solution to increase student-centred learning"*. Most teachers appreciated the utility of the interactive simulations demonstrated as part of the TPD programs and were willing to include them in their current teaching, if such ready-to use simulations are available: *"it would be beneficial if more models are added to a repository, so that teachers and interested students can use the methodology in an easy and systematic way."* However, many were skeptical about adopting and implementing the tools within the current curriculum framework. A majority of the teachers opined that a shift towards exclusive online mode of teaching was challenging, but enactment of many complex concepts using virtual labs, videos were beneficial for students: *"in online teaching, we are able to visualize many things better."* In terms of wider adoption of technology in the teaching-learning process, the lack of sufficient infrastructure to support technology-oriented education was a great concern: *"availability of infrastructure for the students needs to be ensured"*. Smartphones are widely used as a medium for instruction, and suggestions were made to develop interactive tools which are mobile compatible: *"I have a suggestion to develop software similar to learnware which is android friendly so we can overcome the limitation of infrastructure....."*.

DISCUSSION AND CONCLUSION

The success of a model as described depends on long term sustainable collaborations between the three stakeholders involved. Towards this direction, the following policy changes were initiated following the workshops: 1) It was decided to conduct more training workshops, ensuring participation and involvement of more teachers from different parts of the state. Providing such regular TPD opportunities would help teachers build confidence in the novel pedagogical interventions. 2) As teachers indicated, availability of well-packed and easily accessible interactive tools would accelerate the adoption of modeling-based pedagogy. To address this, steps have been initiated to design more interactive tools with teachers as co-designers. 3) Realizing the need to equip teachers and students towards CM based education, efforts are being made to extend the TPD programs to school teachers as well. In summary, we presented the way we analyzed a global education problem, and a tripartite model we developed to operationalize the implementation of some of the policy recommendations of NEP 2020, through a collaboration between a research institution, a policy making body of a state government, and practising teachers. The partnership model we developed provided the opportunity for:

- an official of a state-level policy-making body to collaborate on curriculum design
- modelers and teachers (practitioners) to work with and extend novel techniques and tools developed by a science education research institution
- identifying and understanding challenges faced by teachers, thus providing directions to develop and refine policies, based on design-based evidence
- exploring government funding to develop resources to support model-based learning

Ongoing changes in STEM practice requires students to develop novel computational thinking and problem-solving skills, to address highly interdisciplinary challenges. To design and evaluate novel policy frameworks that could transition education in this direction, it is important for policymakers to become better informed about the value of evidence-informed policymaking. The collaboration model we present, between a policy-making institution (KSCSTE), a research institution (HBCSE), modelers, and other stake-holders (teachers), could be developed further into an evidence-based policy making model, wherein policy innovations can be framed and implemented based on evidence from design-based research.

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STRAND 2: COGNITIVE AND AFFECTIVE STUDIES IN STEM EDUCATION

BIOLOGY TEACHERS' PLANNED PEDAGOGICAL CONTENT KNOWLEDGE IN RESPIRATION: A CASE OF A ZAMBIAN SECONDARY SCHOOL

Thumah Mapulanga[1,a,!], Gilbert Nshogoza[2,a,#], Ameyaw Yaw[3,a,*]

[1]African Centre of Excellence for Innovative Teaching and Learning Mathematics and Science, University of Rwanda, College of Education, Rwanda

[2]University of Rwanda, College of Science and Technology, School of Sciences, Rwanda

[3]University of Education, Faculty of Science Education, Department of Biology Education, Ghana

[a]he/him/his

!thumahm@gmail.com, #jinshogoza@gmail.com, *syameyaw@yahoo.com

This case study compared three biology teachers' planned Pedagogical Content Knowledge (plPCK) in respiration at a secondary school in Chipata District of the Eastern province of Zambia. The teachers attended face-to-face interviews about their planned respiration lessons. The interviews were recorded on audio and transcribed using the same words which were used by the teachers. Using Mavhunga and Rollnicks' model of PCK as the analytical framework, the transcripts were analysed for the teachers' integration of the plPCK components. The findings indicated that although the teachers taught at the same school, there were some differences in the way the teachers integrated the plPCK components. The implications of the findings for teaching and learning were discussed. Through this study, a contribution is made to the debate on teachers' planned PCK in the teaching of respiration. A major recommendation is made to use teacher professional development (TPD) programs that promote knowledge sharing among teachers to enhance the teachers' integration of PCK components in their planning and subsequent teaching of respiration to close the teachers' professional knowledge gap.

Keywords: *biology teachers, planned pedagogical content knowledge (plPCK), respiration.*

INTRODUCTION

Biology is taught as a required subject in many curriculums across the world, including the Zambian secondary school curriculum. This is because biology is a required course for students interested in science-related vocations such as medicine, natural resources, agriculture, food science, and biology education. Individuals can also be empowered to behave ethically by having knowledge and skills in areas such as personal health and environmental safety. However, many students find learning some biology topics difficult, which may lead to low examination results and hinder them from pursuing biology-related vocations. Respiration is one of the topics which students find difficult to learn owing to its abstract nature (Cakir et al., 2002; Kose, 2008). The teachers' Pedagogical Content Knowledge (PCK) is one of the central factors that influence students' understanding of science concepts as it enables teachers to transform content so that students of different abilities can easily comprehend it. PCK represents the teachers' representation and formulation of the content to make it comprehensible to others (Shulman, 1986). Research suggests that teachers who possess developed PCK can transform content and hence help students understand the content (Mavhunga & van der Merwe, 2020). It follows that teachers who possess limited PCK may not be able to make students understand the content.

Many researchers have studied PCK although with varying approaches and focuses. Some researchers have concentrated on teachers' ability to integrate the PCK components thus taking the 'integrative nature' of PCK (Aydin et al., 2015; Mavhunga, 2018; Mavhunga & van der Merwe, 2020; Park & Chen, 2012; Sæleset & Friedrichsen, 2021). These studies reported on teachers' ability to integrate or connect the PCK components as a measure of the quality of one's PCK. The teachers' PCK has been investigated in many science topics including chemical equilibrium (Mavhunga & Rollnick, 2013), mole concept (Mweshi et al., 2019), electromagnetism (Coetzee et al., 2020), force and motion (Azam, 2020; Suh & Park, 2017), genetics (Mthethwa-Kunene et al., 2014), and heredity and photosynthesis (Park & Chen, 2012). Given that PCK is topic-specific and that the PCK required for each topic may be different, there is a need to investigate teachers' PCK in other topics which are perceived to be difficult for some teachers and students. Although respiration is an important topic in the biology curricula and is considered difficult for many students in Zambia (Examinations Council of Zambia, 2016) and abroad (Cakir et al., 2002; Kose, 2008), the above studies did not investigate teachers' PCK in respiration. To fill this gap, the current study sought answers to the question: Does the biology teachers' planned pedagogical content knowledge in respiration differ when teaching at the same school?

REVIEW OF LITERATURE

Shulman (1986) postulated that pedagogical content knowledge (PCK) comprises the teachers' knowledge of regularly taught topics; forms of representing the topics; analogies, illustrations, examples, explanations, and demonstrations; and ways of representing and formulating the subject to make it comprehensible to others. Therefore, teachers' PCK is a central component of their professional knowledge that influences the teaching and learning of regularly taught topics.

Over the years, researchers have studied PCK and defined it as the knowledge needed and used to transform the content into forms that others can comprehend. However, studies maintain that PCK is complex and comprises distinguishable yet inseparable components (Coetzee et al., 2020). Mavhunga and Rollnick (2013) proposed a model of topic-specific PCK (TSPCK) comprising five components: (i) Curricular Saliency [CS] (ii) Students' Prior Knowledge including misconceptions [LP] (iii) what makes a topic easy or difficult to understand [WD] (iv) Conceptual Teaching Strategies [CTS], and (v) Representations including analogies [RP]. Considering the usefulness of the TSPCK model in the teaching of specific topics, there is a need to explore the interaction of TSPCK components (Mavhunga, 2018). Therefore, the current study explores the interaction of the TSPCK components that teachers draw upon when planning to teach respiration.

The Revised Consensus Model (RCM) of PCK is among the latest research works on PCK by experts in the PCK community (Hume et al., 2019). The RCM describes knowledge and experiences that inform the teaching of science (Carlsen & Daehler, 2019). The model categorises PCK into three realms namely; collective PCK, personal PCK, and enacted PCK. Personal PCK (pPCK) describes each science teacher's professional knowledge (Carlsen & Daehler, 2019). Mavhunga and van der Merwe (2020) divided personal PCK into planned PCK (plPCK) and enacted PCK (ePCK). While planned PCK refers to the PCK teachers demonstrate when planning, enacted PCK is the PCK teachers demonstrate when teaching. This study focused on exploring secondary school teachers' planned PCK in respiration when working in the same teaching and learning context. The learning context is recognised as an essential component of PCK which influences the teaching and learning processes. The learning context describes various contexts under which teaching and learning may occur such as school and student attributes through which teachers' knowledge and skills are amplified and filtered (Carlsen & Daehler, 2019). The current study explores whether the school as a learning context may influence teachers' plPCK in respiration.

RESEARCH METHODOLOGY

Research Design and Sample Selection

The qualitative case study approach was adopted to describe in-depth three biology teachers' planned PCK (plPCK) using data from lesson plans and in-depth lesson planning face-to-face interviews (Creswell, 2012). In this study, the case refers to teachers teaching at the same school. The case study approach was preferred because it enabled gaining insight into the world of the participants and to describe their perceptions about teaching respiration. Three biology teachers teaching at a secondary school in Chipata district in the Eastern province of Zambia were purposively selected because of their experience in teaching respiration. The participants included one male with a secondary teachers' diploma and 11 years of teaching experience, one female with a certificate in Agriculture and 2 years of teaching experience, and one female with a secondary teachers' diploma and 8 years of teaching experience. The District Education Board Secretary and the Headteacher of the selected school granted authority to conduct the study. The participants took part in the study voluntarily and were assured privacy of their identity and that of the school at which they taught.

Methods and Data Collection Instruments

The lesson planning interview guide (Friedrichsen et al., 2009) was adapted and used to conduct the face-to-face lesson planning interviews. The interview guide was divided into six sections - biographic information, and five PCK components of the Mavhunga and Rollnick's model of PCK. The interview guide was validated by peers and experts in the field of biology education to ensure that the data collected was relevant to answer the raised research question.

The same lesson planning guide was distributed to the teachers requesting and guiding them to prepare a lesson each on respiration. Each teacher's lesson plan was collected and carefully analysed for evidence of plPCK components which were used to examine the teacher's pedagogical reasoning during the interviews. The interviews were conducted at the teacher's convenience and took about 20 minutes. The audio-recorded interviews were transcribed word for word. The interviews were centered on planned teaching and learning activities such as respiratory principles, teaching techniques, students' prior knowledge and misunderstandings, teaching aids, and other PCK components. The interview tried to elicit the teacher's thinking for the lesson planning decisions.

Data Analysis

The interview transcripts were analysed qualitatively by identifying evidence of the integration of plPCK components based on Mavhunga and Rollnick's model of TSPCK. The enumerative approach (Park & Chen, 2012) was used to indicate the connections among PCK components on a PCK map by indicating one frequency count for each connection between any two plPCK components identified in the interview transcript. The frequencies were then summed up and a

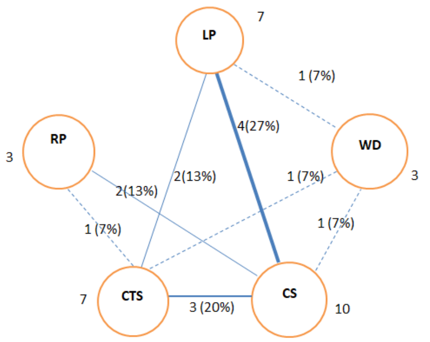
PCK map for each participant was constructed. Thicker lines indicate strong connections (high frequencies) between the plPCK components. There are ten (10) possible connections among the five plPCK components. The quality of the teachers' plPCK was determined by the number of the plPCK pairs they connected in the plPCK maps (irrespective of the frequency of connections).

To illustrate the analysis procedure, consider the case of Chabota who planned to use a chart in his lesson plan, during the interview he was asked how the chart would help the pupils to learn about respiration. He linked his knowledge of RP and CS when he responded: "*On the chart, the pupils are able to see that during respiration…. the chemical reaction takes place where energy, carbon dioxide, and water are liberated*". A frequency count of one (1) was recorded for this link between RP and CS. Similarly, the transcripts of each teacher were examined for the teachers' integration of the plPCK components as shown in Figure 1.

FINDINGS

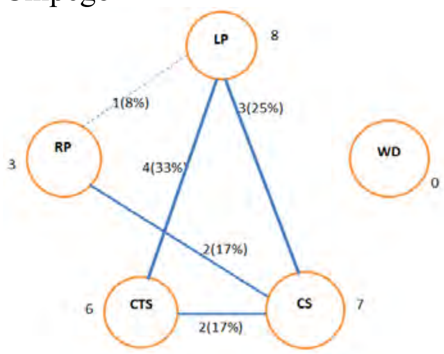
The plPCK of the three teachers is presented and described in Figure 1.

Chabota



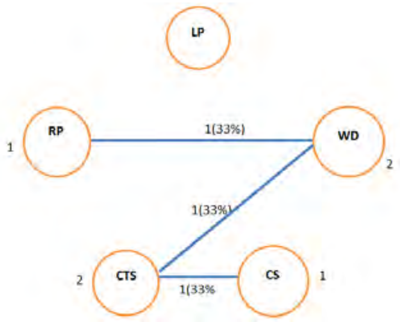
Number of plPCK pairs that were connected: 8/10
% of connections made among plPCK pairs:
8/10 *100 = 80%
Quality of plPCK: 80%
Level of plPCK: Developed

Chipego



Number of plPCK pairs that were connected: 5/10
% of connections made among plPCK pairs:
5/10 *100 = 50%
Quality of plPCK: 50%
Level of plPCK: Emerging

Choolwe



Number of plPCK pairs that were connected: 3/10
% of connections made among plPCK pairs:
3/10 *100 = 30%
Quality of plPCK: 30%
Level of plPCK: Limited

Figure 1 Teachers' planned PCK maps

The plPCK maps in Figure 1 show that the most integrated plPCK components were curricular saliency (CS) followed by learners' prior knowledge and misconceptions (LP), while the components what makes the topic difficult to learn (WD) and Representations (RP) were least integrated. The components CS, conceptual teaching strategies (CTS), and RP were integrated by all three teachers. Further, although the teachers taught at the same school (context), their plPCK varied greatly. Their ability to reflect on their students, teaching resources, and content was also different. The results show that Chabota made 8 of the 10 possible connections among the plPCK components representing 80%, Chipego made 5 of 10 (50%) connections while Choolwe made 3 of 10 (30%) connections. It follows that Chabota had a more developed plPCK (80%), Chipego had an emerging plPCK (50%) while Choolwe had a limited plPCK (30%). The more experienced teacher [Chabota] had the most coherent PCK structure with 28 connections among the five plPCK components. For him, experience may have contributed to his plPCK structure. Interestingly, the least experienced (novice) teacher [Chipego] had the second most coherent plPCK structure with 24 connections among four of the plPCK components. Her [Chipego] plPCK structure was more coherent than that of Choolwe (with 6 connections among four plPCK components) who was more qualified and experienced than her [Chipego]. For Choolwe, experience and qualification did not seem to contribute to a coherent plPCK structure. These findings have implications for teaching and learning as discussed in the following section.

DISCUSSION

The study found that although the teachers taught at the same school and planned to teach students of similar abilities and backgrounds, their plPCK was idiosyncratic and the components were uniquely integrated. This result is similar to and thus confirms the findings of other studies that explored the interaction among the plPCK components (Mavhunga, 2018; Park & Chen, 2012; Suh & Park, 2017). The results confirm the existence of TSPCK in the personal PCK realm during planning. The quality of teachers' plPCK as demonstrated by their ability to integrate the plPCK components has classroom implications because what the teachers do in class is informed by their PCK (Park & Oliver, 2008).

The study also found that the teachers demonstrated at least four of the components of plPCK in their plPCK maps. However, the quality of teachers' PCK depends on the knowledge of the individual PCK components and their interaction (Mavhunga & Rollnick, 2013). Chabota demonstrated developed plPCK given the high number of connections made among the five PCK components. Although Chipego and Choolwe both demonstrated knowledge of four plPCK components, Chipego's plPCK was more developed as she made more connections among the PCK components. These differences in the quality of teachers' plPCK support the person-specificity of PCK (Suh & Park, 2017).

Concerning how the plPCK components were integrated, the component of learners' prior knowledge and misconceptions (LP) was often connected to conceptual teaching strategies (CTS) in Chipego's plPCK map. This suggests that by using the knowledge of students to select conceptual teaching strategies, Chipego held a constructivist view of teaching respiration. On the contrary, the low and lack of connection between LP and CTS in Chabota and Choolwe's plPCK maps respectively suggests that they held a deductive approach to teaching respiration (Soysal, 2018).

The connections between LP and curricular saliency (CS) which were dominant in Chabota's

PCK are important for enabling teachers to make pedagogical decisions concerning the content and conceptual teaching strategies for delivering that content (Lee & Luft, 2008). The interaction of the teachers' plPCK components reveals the sophistication of PCK and provides more insight into PCK in general. Further, the teachers' knowledge of at least one plPCK component contributes to their understanding and application of the other components and also provides a prerequisite for supporting the teachers to develop their PCK during professional development programs.

The context specificity of plPCK could be taken to imply that teachers teaching in the same context would demonstrate the same or similar PCK structures given that they generally access the same teaching and learning materials, content, and ability of learners. However, this study shows that teachers teaching at the same school demonstrate different quality/structures of plPCK. This result supports the assertion by Carlen and Daehler (2019) that teachers' PCK (including personal PCK) is unique and different because teachers have different attitudes and beliefs which filter their PCK.

Research has shown that formal education and teaching experience have the potential to develop, shape, and refine one's PCK (Carlsen & Daehler, 2019). As such, some studies found that teaching experience influences the development and quality of teachers' PCK (Azam, 2020; Lee & Luft, 2008). However, in the current study, although Chabota and Choolwe had trained from the same university, may have received the same formal training, and had relatively longer teaching experience, their plPCK were significantly different. Further, the results show that teachers' qualifications and experience may not be the only factors influencing one's plPCK as evidenced by a less experienced (novice) and less qualified teacher [Chipego] who demonstrated a more coherent plPCK structure (emerging plPCK) than a more experienced and qualified teacher [Choolwe] who demonstrated limited plPCK. This result supports Mim and Jahanara (2017) who found that experienced teachers demonstrated limited PCK in genetics. These results may signify the effect of teachers' attitudes and beliefs in filtering and amplifying teachers' plPCK. The variation in teachers' plPCK may have been influenced by teachers' attitudes and beliefs about the teaching and learning process (Barendsen & Henze, 2019).

CONCLUSION AND RECOMMENDATIONS

The findings of the study show that teachers working in the same context such as teaching at the same school and hence teaching students with a similar background may have variations in the quality of their plPCK. The variation in the teachers' plPCK could be explained by the person-specificity of PCK, and other factors within the learning context. The findings suggest a need to improve teachers' PCK in respiration through professional development programs such as lesson studies. Future research should use a larger sample, and multiple data collection methods such as lesson observations, reflective journals, and students' perceptions to support and increase the validity of the findings. A threat to the credibility of the findings of this study is that most of the data in the study were self-reported through interviews, and the teachers' views would not be confirmed without observing their lessons. To offer some credibility to this methodological issue, in-depth descriptions of the teachers' plPCK were made. Since a small sample was involved in the study, the findings should be interpreted and applied cautiously and to similar contexts.

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CHANGES IN MONASTIC SCIENCE LEARNING MOTIVATION AND ENGAGEMENT DURING A SIX-YEAR CURRICULUM

Kelsey Gray[1] and Tashi Lhamo[2]

[1]Chapman University, [2]Drepung Loseling Meditation and Science Center

[1]kelseygray2012@gmail.com, [2]tashilhamo652@gmail.com

Led by His Holiness the Dalai Lama, the initiative taken by the Tibetan Buddhist monastic community to connect with western science and scientists presents a unique opportunity to understand the motivations and engagement behaviors that contribute to monastic science learning. In this study, we draw on quantitative data from two distinct surveys that track motivations and engagement behaviors related to science education among monastic students. The first survey was administered at one monastic university in 2018, and the second follow-up survey was completed by students at two monastic universities in 2019. These surveys assessed the reception of science education related to motivations among monastics and their demonstration of engagement-with-science behaviors. We also tested for variation over time by surveying students in all years of the science curriculum. We identified that monastic students are motivated by their perception that studying science has an overall positive effect and benefitstheir Buddhist studies, rather than negatively affecting their personal or collective Buddhist goals. In accordance with this finding, monastics behave in ways that encourage fellow scholars to engage with science concepts. Survey responses were disaggregated by years of science studyand indicated changes in motivation and engagement during the six-year science curriculum.

These insights support the relevance of considering motivation and engagement in a novel educational setting and inform ongoing work to expand the inclusiveness of science education. ***.*** *Our findings provide direction for future avenues of enhancing exchange of knowledge and practice between Buddhism and science.*

INTRODUCTION AND BACKGROUND

Many theories and conceptual frameworks seek to describe and explain academic motivation andengagement. With the aim of gaining greater clarity in this space, there have been calls for additional co-consideration of motivation and engagement (Martin, 2007, 2009; Murphy & Alexander, 2000; Pintrich, 2003; Reschly & Christenson, 2012). In the present study we explore motivation and engagement of a unique sample of students: Buddhist monastic university students who participated in a curricular innovation to include science in their monastic education. The educational history of these students includes extensive philosophical training and little to no exposure to western science. We address questions about their motivations and engagement, specifically how these students perceive the value of the science curriculum and theextent to which they participate in activities related to science outside of the classroom. Our goalis to contribute to the ongoing conversation in the motivation and engagement domain through exploration of these concepts in a cross-cultural educational environment.

Introduction of western science in Tibetan monastic education

The introduction of science in Tibetan monastic education originated from the vision of the

DalaiLama who called for comprehensive science education at Tibetan monastic universities. This callwas based on decades of personal experience in dialogue with western scientists from which he concluded that, in many significant respects, Buddhism and western science share common purposes and complementary perspectives (Dalai Lama, 2005).

In 2013, monastic leaders in the Gelug Buddhist tradition decided to implement the science program, ushering in the most substantial curricular innovation in 600 years of monastic education (Gray and Eisen, 2019). The following year, a 6-year science curriculum comprising biology, neuroscience, and physics and supplemented by math and philosophy of science, was introduced in the three largest monastic universities of south India (Gray and Eisen, 2019). This curriculum had been piloted during a 6-year development phase. Introduction in the monasteries was incremental such that the first year of the curriculum was offered in the first year of the initiative, then curricular years one and two were taught the following year, and so forth until allsix years of the curriculum were implemented. ETSI summer session courses are taught in both English and Tibetan. During class, western science instructors speak a few sentences at a time inEnglish, then an interpreter translates the information into Tibetan. The Tibetan language has roots as a liturgical language for Buddhist teachings, 'the language of *dharma'* (Tournadre, 2013). Given these origins, there were few terms for specific scientific phenomena prior to the introduction of science curricula. Through annual translation conferences, over 5,000 scientific terms have been added to the already rich Tibetan language (Gray et al., 2020).

Numerous factors influence the Tibetan Buddhist monastic experience of learning science in thiscontext. Monastic students enrolled in science education are adult learners with a highly developed conceptual framework and are already scholars themselves. These students join the science curriculum after completion of approximately 13-17 years of Buddhist study. Monastic students progressed through each year of the science curriculum in sequence. For example, 5th year participants have been in the science program for five years. Examining monastic scholars' motivations and perceptions of this science education experience and related behaviors provides unique and valuable insight on how motivation, engagement and cultural factors can influence science learning

METHODS

Study Approach

To characterize Buddhist monastics' motivations and engagement related to learning science in the ETSI program, we conducted two studies at two monasteries and time points to yield over 900 monastic survey responses that inform the present report. Specifically, the research questionsthat these surveys addressed are:

How do monastic students self-report their motivations in terms of the impact ofscience learning on their Buddhist studies?

How do monastic students engage in science activities outside of the classroom?

Do motivations and engagement related to science learning change during the six-year science curriculum?

Participants, Instruction, and Surveys

During ETSI summer workshops, monastic students attended science class four and a half hours per day, six days a week. For each science course (physics, biology, and neuroscience), they received instruction for seven days, reviewed material on the eighth day, and took a final exam ineach topic area at the conclusion on instruction. Each class was led by a teaching team consistingof two visiting faculty, two translators, and a monastic teaching assistant. First- and sixth-year students took an additional class discussing the philosophy of science to bridge their training in philosophy with their science education. Since the workshop was held annually for six years, students began science education learning fundamental concepts of each discipline in the first year and pursued topics of increasing complexity through the sixth year. In neuroscience, for example, Year 1 students were taught basic concepts of the neuron, the action potential, and functional neuroanatomy, while Year 6 students grappled with language processing, learning andmemory, and consciousness.

A variety of active learning strategies were employed to maintain monastic engagement with science learning, including techniques used by monastics in their own Buddhist study such as debating and the Socratic method of asking and answering questions to engender critical thinking, and traditional western techniques such as hands-on labs, experimentation, and computational learning through interactive videos.

This study aimed to track perceptions and behaviors of Buddhist monastic students as they underwent this novel forum of science education over the six-year curriculum. To this end, two distinct surveys (see Supplemental material) were administered to study how monastics' perceptions and behaviors related to engagement and motivation in science learning and the extent to which studying science affected their Buddhist studies. Further, to investigate how perceptions change over time, and whether they are commonly held across different monastic populations, responses were compared across years of study in the program and at two different monastic universities.

Study 1: In 2018, monastics from curriculum years 1 to 5 at Sera Jey Monastic University participated in a survey at the end of the summer session (n=214). This survey collected self-reported demographic data including level of English proficiency, science education background, and years of participation in the summer science program (Table 1). To investigate monastics' perceptions of the role of science in relation to their Buddhist studies, students selected promptscategorized as describing either positive or negative perceptions. Positive perceptions included whether science played a role in shaping, engaging, understanding, or validating Buddhist studies. Negative perceptions included taking away too much time, being a distraction, a contradiction, or not useful for Buddhist studies. To examine specific behaviors resulting from their perceptions and exposure to science, participants rated frequency of hearing, using, and accessing science learning materials outside of class time, as well as their likelihood of encouraging fellow monks to study science on a 5-point Likert scale (1=none/never, 5=stronglylikely/very often).

Study 2: To assess the generalizability of initial findings from Study 1, and to probe whether observations at Sera Jey were similar to those at another site where the ETSI program was implemented in a similar fashion, Gaden Monastic University (400 km from Sera Jey), a second survey was administered in 2019 at both Sera Jey (n=427) and Gaden (n=296) Monastic Universities to students who participated in years 1 to 6 of the program. This survey tapped monastic perceptions of gains from participation in the ETSI program at their monastery, including learning science content knowledge, personal gains, and benefits to their Buddhist studies. Participants rated these contributions on a 5-point Likert scale (1=none/never, 5=strongly likely/very often).

Translation of surveys used in both Study 1 and Study 2 from English to Tibetan was performed by an experienced monastic translator and then independently verified by a second senior non-monastic translator. Students responded to online surveys given to entire classes in the presence of both the Tibetan-English translator and the western science instructor. All surveys were administered upon completion of the year's ETSI summer program. Survey questions are included as supplemental materials (Supplemental 1). Although prompts were communicated tostudents by English-Tibetan translators, we cannot be sure that definitions, conceptualization, and interpretation of terms were consistent among all survey responders. This is difficult to achieve even when survey items are generated and responded to in the same language and similar cultures (Limeri et al., 2020).

DATA ANALYSIS

In the 2018 survey, students were presented with 10 items (five positive and five negative) and asked to choose all items that described their perception of their science learning experiences. The percentages of participants who chose each of the five positive and five negative items werecompared across all years of study. A two-way ANOVA examined perceptions (positive, negative) for all years of study (1-6), and their interaction. To assess specific behaviors related tolength of exposure to science learning (2018 study) and to investigate the overall associations of science study to science content knowledge, personal gains, and Buddhist studies (2019 study), responses on 5-point Likert scales were averaged, and data are presented as the mean and standard error mean of responses. ANOVAs analyzed behaviors, year of study, and their interaction. For all ANOVAs, Tukey's multiple comparisons post-hoc analyses were conducted to investigate group differences, and effect sizes are reported as R^2. Analyses were conducted in GraphPad Prism version 8.3.0; criterion for significance was $p < 0.05$.

RESULTS

Student Background

To characterize relevant background differences among Tibetan Buddhist monastics in the context of science education, information was collected on English language proficiency and science education history from ETSI students at Sera Jey monastery in summer 2018 (Table 1). Responses revealed that 5% of surveyed students were fluent in English (n=214) and 51% understood at least half of the content communicated through spoken English. Nearly half of thestudents (46%) were exposed to science education only through the summer intensive ETSI program, 14% of students had studied science in a secular school before joining the monastery, and 34% studied science independently. Anecdotally, students with previous English and/or scientific knowledge often facilitated knowledge exchange in the classroom.

English Language Proficiency	% Participants
I don't understand any English	44%
When someone speaks English, I understand 50% or more of what is said.	51%
I am fluent in English.	5%
Science Education Background	
I have only studied science in the ETSI program.	46%
I have studied science in a secular school.	14%
I have studied science independently.	34%
I have studied science in other science programs for monastics, beyond ETSI.	7%

Table 1. English language proficiency and science education background among monastic

students taking Emory-Tibet Science Initiative (ETSI) science classes in summer 2018 (n=214).

Monastic student perceptions and behaviors related with ETSI science education at SeraJey Monastery (Study 1, 2018)

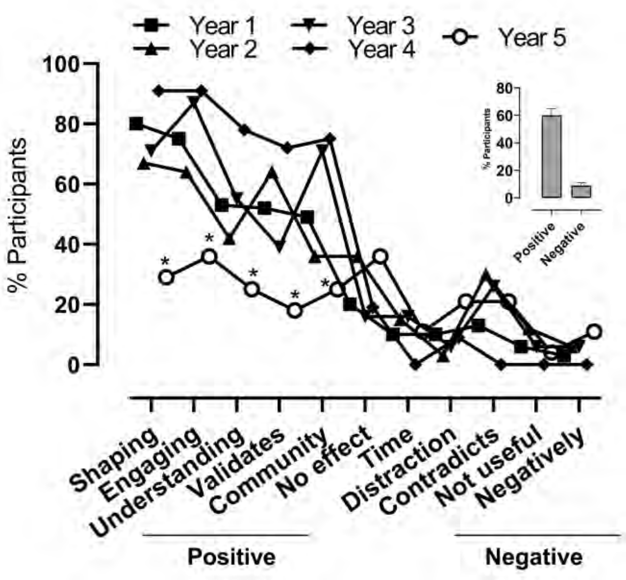

Figure 1. Monastic students' perceptions on effects of learning science at Sera Jey MonasticUniversity (2018 study) In summer 2018, Tibetan Buddhist monastic students reported a robust appreciation for the positive versus the negative effects of learning science on their Buddhist studies; determined by the frequency of survey responses as a percent of participants in each year(n=214). Each symbol is representative of data from students in different years of the science curriculum. The words chosen as graph labels are underlined in the full prompt (Supplemental A,number 7). Overall percent of participants endorsing positive and negative perceptions are quantified in the inset.

A high percentage of monastic students endorsed positive effects of studying science on their Buddhist philosophical and religious studies (Figure 1, inset). Across all years of participation inthe science curriculum, 57 - 71% of monastics identified some positive effects, while only 4 - 30% of monastics selected negative effects. The number of reported positive and negative perceptions differed significantly, F (1, 4) = 19.88, $p<0.05$, $R^2 = 0.74$.

Among positive statements, those most frequently selected across all years of science study werethat science learning helps in: 1) engaging other philosophies in understanding Buddhism (70.6%) and 2) shaping what it means to be a monastic in the 21st century (67.6%). Further analysis detected a significant and robust effect of years in the program on positive perceptions of studying science, F (4, 16) = 23.85, $p<0.0001$, $R^2 = 0.70$. Notably, year 5 responses were significantly lower for all positive effects compared to those of students in early years, $p<0.0001$.Among the negative statements, the most frequently selected across all years of science study were that learning science: 1) contradicts Buddha's teachings with respect to origins of life and the universe (18%) and 2) harms my Buddhist studies because it requires too much time. (10.4%). We observed a significant effect of years of study (F (4, 16) = 3.35,

$p<0.05$), but with a small effect size, $R^2 = 0.30$, in which Year 4 students less frequently endorsed four of the five negative effects compared to students in all other years.

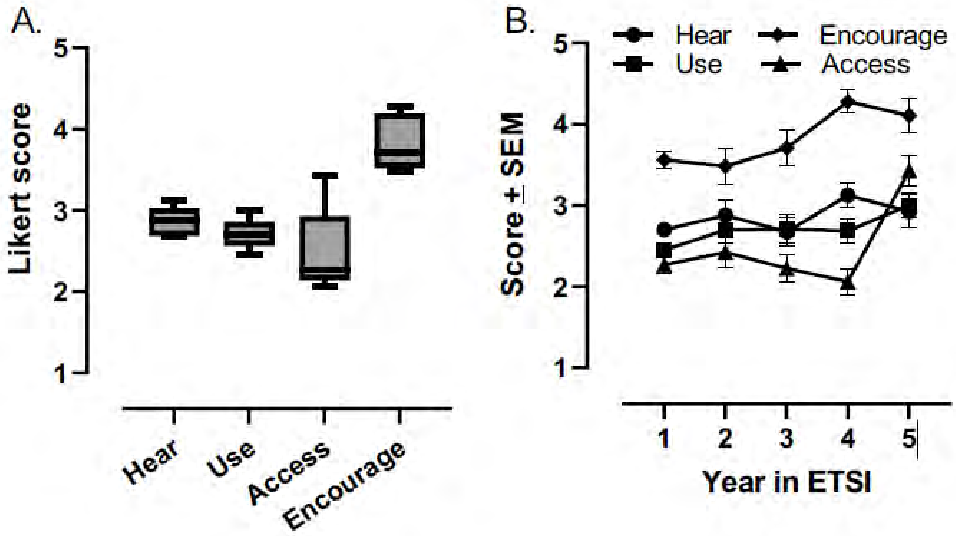

Figure 2. Monastic students' science learning behaviors at Sera Jey Monastic University (2018 study) A) Willingness to encourage fellow monastic students to study science was rated significantly higher on a Likert-type scale of 1-5 than practical behaviors of hearing science words, using science terms, and accessing science content outside of ETSI (n=214). **B)** Disaggregated by year of study in ETSI, monastic student levels of engagement increased as a function of years in the program. In particular, accessing science materials significantly increased with Year 5 students compared to all other years; p<0.0001; Tukey's test. Each symbolis representative of a different science learning behavior.

With respect to science learning behaviors, monastic students in all years of study strongly endorsed the likelihood of encouraging fellow monastics to study science, with the highest mean Likert scores (3.8 $\pm$ 0.1), and with lower scores on hearing (2.8 $\pm$ 0.1), using (2.6 $\pm$ 0.1), and accessing (2.4 $\pm$ 0.1) science concepts outside the classroom. (Figure 2A). To further investigate trends in engagement with science material outside of class, a two-way ANOVA revealed a significant effect of year of study on reported behaviors F (4, 1040) = 13.77, $p<0.0001$, $R^2 = 0.04$and a significant interaction between year of study and behavior, F (16, 1040) = 2.49, $p=0.001$, $R^2 = 0.03$. (Figure 2B). In particular, Tukey's post-hoc tests comparing all possible combinations revealed that Year 5 students more frequently reported accessing science information in the Tibetan language than did students ($p<0.0001$, comparing Year 5 to all other years). Furthermore, scores on the relevance of science in Buddhist studies and on encouraging fellow monastics to study science significantly increased over time, based on comparison of Year1 to Year 4 responses ($p<0.01$, comparing Year 1 to Year 4 responses).

Monastic student perceptions regarding benefits of science learning at Sera

Jey and Gaden Monastic Universities (Study 2, 2019)

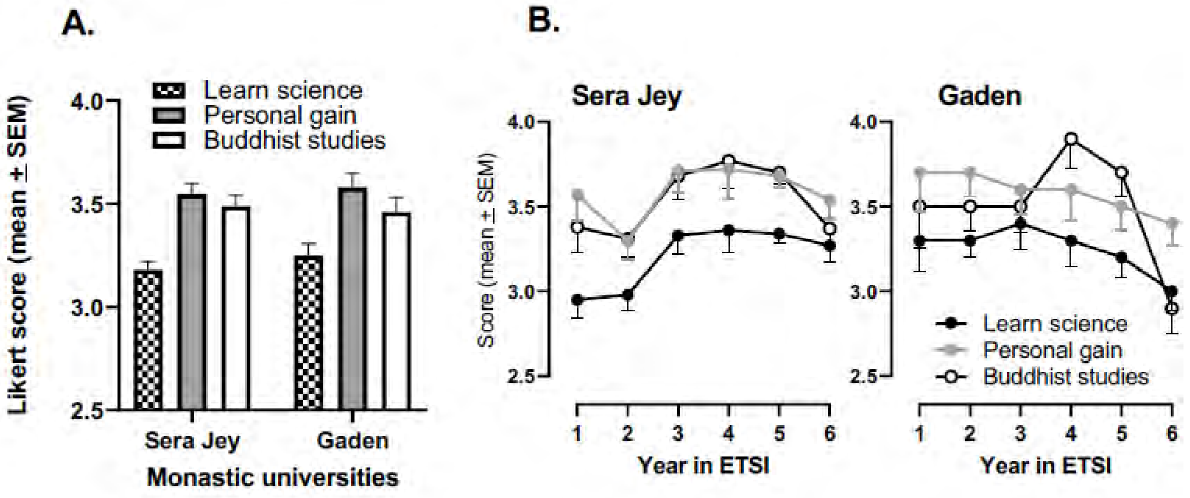

Figure 3. Monastic students' perceptions on benefits of learning science at Sera Jey and Gaden Monastic Universities (2019 study) A) At Sera Jey and Gaden monasteries, monastic students rated learning science content as a benefit of participation significantly lower on a Likert-type scale of 1-5 compared with personal monastic gain or benefits to their Buddhist studies, p<0.0001 and p=0.0003 for Sera Jey and Gaden, respectively. **B)** At Sera Jey and Gadenmonasteries, all perceived benefits increased as students responded from Year 1 to Year 4, and Likert scores began to decline for the Year 5 and 6 students. Each different circle style is representative of different perceived benefits of learning science.

The second study aimed to elicit additional perspectives on the benefits of science education. At both monasteries, monastics reported significantly lower mean scores on actually learning science as a benefit of participation in the science curriculum, compared to personal gain or benefits to Buddhist studies, $p<0.0001$ and $p=0.0003$ for Sera Jey and Gaden, respectively (Figure 3A). Further comparison by two-way ANOVA (monastery x benefit) revealed no significant interaction or difference between the two monasteries for each perceived benefit F (2,2169) = 0.26, p =0.61.

Analysis of responses by year of study in ETSI revealed that for both monasteries, all perceived benefits increased among students from Years 1 through 4, yet mean Likert scores were lower among Year 5 and 6 students (Figure 3B). Two-way ANOVAs identified a significant effect of participating year in science curriculum on reported benefits gained by science education, F (5, 1260) = 6.5, $p<0.0001$, R^2 = 0.02 and F (5, 999) = 3.7, $p<0.01$, R^2 = 0.02, for Sera Jey and Gaden, respectively.

DISCUSSION

Monastic students report a robust appreciation for the positive effects and benefits of studying science on their Buddhist studies

The robustly positive effects we observed likely are linked primarily to the perceived connections between science learning and enhancing Buddhist studies. For example, the most frequently selected positive effects of studying science were that 1) it contributes to shaping whatit means to be a monastic in the 21st century and 2) it is a means of engaging other philosophies to help the development of Buddhist philosophy (Figure 1). Students also affirmed that science learning benefits their Buddhist studies and produces personal gain to a significantly greater degree than the inherent learning of science (Figure 3A). These findings detail specific positive perceptions that monastics endorse about their science learning experience. Notably, these findings are found in the Year 1 through Year 4 students, whereas Year 5 monastics' positive perceptions declined significantly. This difference could be attributed to two opposing forces.

Year 5 and 6 students begin preparing for the rigorous Gelug exams, while Years 1 through 4 are enthusiastic for the summer enrichment that ETSI brings, temporarily changing the demanding year-round schedule of the monasteries.

Monastic students enthusiastically encourage fellow monks to engage in and study science.

As shown in Figure 2, students reported on average that they "sometimes" a) hear science terms being used by Tibetan monastics (e.g., in conversations, debates, teachings), b) use science termsoutside of the summer program, and c) access science content in the Tibetan language on the internet, social media, news, or radio. In contrast, the likelihood of their encouragement of fellowmonastics to study science was significantly higher.

Despite the strength of personal beliefs that science learning can positively influence their Buddhist training, the significantly lower scores on hearing, using, and accessing science compared to building a community of science-learning monastics, suggest that the practical utility and frequent exposure to science concepts may be limited. Such a finding indicates that conceptual buy-in is farther along than the more pragmatic coordination aspects that are needed to more effectively promote science learning behaviors outside of the ETSI classroom.

Personal and behavioral factors related to learning science change with science exposureacross the six-year science curriculum

A notable finding of this study is the change in perceptions and behaviors related to science learning as a function of year in the ETSI program. As monastics participate in consecutive ETSIsummer programs from years 1 through 4, they increasingly report positive effects of the experience (Figures 1 and 3B), are more likely to refer to science concepts outside of the classroom setting, and increasingly encourage fellow monastics to pursue science education (Figure 2B). However, monastic students' perceptions on the benefits of science education significantly decrease in Years 5 and 6 (Figure 1 and 3B, respectively). We suggest that these changes are attributable to the competing demands of participation in the ETSI summer program against increasing pressure to study for the Gelug Buddhist exams taken by many Year 5 and Year 6 students. As monastics reach advanced stages of their Buddhist studies, they become eligible to start taking the Gelug exams for the highest academic Geshe degree. Monastic students in Years 5 and 6 expressed concern that participation in science studies eroded time for adequate preparation for those all-important exams. For example, it was reported by monastic science directors that scholars enrolled in these years sought exemption from labs (Sera Jey) or from the science classes entirely (Gaden). By contrast, monks in the early years of ETSI may be more likely to participate in science activities throughout the year, in addition to the ETSI summer program.

Consistent differences in monastic students' perceptions of the benefits of learning science in theearlier versus later years of science exposure are maintained across two monasteries, as well as inStudy 1 (2018) and Study 2 (2019) (Figures 1 and 3). The pressure of limited time to study whileattending science classes appears to be a barrier to sustainability of positive science learning perceptions. Nevertheless, the inclusion of formal science knowledge assessment on the Gelug Buddhist exams appears to stimulate students accessing science education materials (Figure 2B), consistent with the need to study and prepare for the science sections of the exams.

Incorporating more frequent, habitual exchange of information via routinization of science classes throughout the entire year (not only summer) may enhance the currently modest access toscience reported by students in Years 1-4. Implementation of such a year-round class schedule isunderway. Encouraging incremental, time-distributed and structured use of science learning materials outside of class in Years 1-4 may buffer disaffection from science studies among Year 5-6 students (Figures 2, 3, and 4) by better preparing them for science questions in their Gelug exams, and reducing the scramble to access science materials in years 5 and 6 (Figure 3B), thereby lowering conflict with urgent demands for Buddhist studies.

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CLASSROOM CHALLENGES BEFORE SCHOOLS IN THE TRIBAL REGIONS

Asmita Redij[1,a,!] and Aniket Sule[1,b,#]

[1]Homi Bhabha Centre for Science Education, Tata Institute of Fundamental Research, Mumbai 400088, Maharashtra, India.

[a]she/her/hers, [b]he/him/his

[!]asmita@hbcse.tifr.res.in, [#]aniket.sule@hbcse.tifr.res.in

Various affirmative actions taken to bring children from the tribal region under the umbrella of literacy have focused on infrastructure, equal access to resources to help them get to school and climb the ladder upward. Still the dropout rate is significant as the children progress to the higher classes, and their representation further diminishes in tertiary education and jobs. Further, at school level, scholastic performance is particularly poor in Science and Math subjects. The authors conducted a survey to investigate the underlying issues.

This exploratory survey reaffirms that most of the students from the tribal regions are still first generation school goers and come from a different socio-cultural background than the mainstream that the classroom practices assume, both in the textbooks and the curriculum. This article gives an overview of the pre and post pandemic classroom challenges in schools serving in tribal regions.

INTRODUCTION

Learning happens as much outside the school setting as inside it. Education is where the person is trained and guided through the process of learning or of acquiring knowledge, skill etc. Educational institutions are to facilitate education of individuals and certification. While knowledge helps to connect that learning to our day to day life, the accreditation/certification is equally essential to excel and make ends meet, and to live a life of dignity and ensure social justice in life.

The Education for All (2000) and Right To Education (2009) policies of the government of India have ensured enrollment of above 97% at primary and middle school level, which means that most children stay in school up to 13 years of age. Yet, the drop-out rate at secondary and higher secondary continues to be large, summing up to 30% as reported by Educational Survey at glance 2018 (ESAG-2018). This drop-out rate is significantly higher amongst the Schedule Tribes (Tribal Ed. survey), who constitute roughly 8% of the total population of India. Most of the students from the scheduled tribes happen to be first generation school goers (Malkani R., 2018). And despite the affirmative action programmes by the government, their representation is consistently low in higher education and jobs. This early dropout has even bigger implications for girls, who are more likely to get married and bear children at an early age.

OBJECTIVE OF THE SURVEY

The purpose of this qualitative study was to understand the educational challenges in a Science classroom faced by first generation school goers between the age group of 13 to 16, who belong to different socio-cultural backgrounds than the mainstream. Through this we aimed to:

- Gain some understanding of the difficulties faced by teachers while teaching the students from the marginalized tribal regions.
- Start to understand the effects of the long closure of schools during the pandemic and the challenges they were facing post reopening of schools

SAMPLING AND METHOD OF DATA COLLECTION

The primary focus group of this study were the children from the age group of 13 to 16 i.e grade, 8, 9, 10. And the teachers who were teaching Science or Mathematics subjects at least a few years before the Covid-19 pandemic that started in 2019, during the period of pandemic and still continue.

Sampling Method.

For this survey, we employed different purposeful sampling strategies (Creswell, 2002). Homogeneous Sampling was used to select the site. We zeroed in on Gadchiroli district of Maharashtra, which is dominated by communities such as the Gond and Madia. They all belong to a similar socio-cultural background, which is distinct from the mainstream culture. The literacy rate in this district of Maharashtra is lower than the state average (Tribal Ed. Survey). The reasons for dropout are many like, inadequate support from family, community and the social segregation, poorer implementation of government policies etc (Ghosh, 2014; Mohamedunni M. & Stephen, 2019; Sahu K., 2014). Snowball sampling was used for selection of schools in this region. And confirming/disconfirming sampling while selecting the teachers for interaction.

Sample size was limited by the restrictions on travel during the pandemic and ease of conveyance in the regions selected. Permissions were taken from the school Principal before interacting with teachers and students. Consent was taken from teachers being interviewed or who filled the questionnaires.

Types of data collected.

The primary data used in this study was collected during the visits to 10 schools after their reopening (in rural India) from August 2021, after a long closure on schools during the Covid pandemic. This includes one-on-one Interviews of teachers and school heads, Questionnaires filled up by the Science and Math teachers, and fieldnotes of the student interactions. Further, we also used the responses sent by students of this region to the Science communication (Redij, A. et al., 2022), which corroborated or countered the findings of the study undertaken.

The teachers who have been teaching Science and Math subjects for at least a year before the onset of the Covid-19 pandemic were given a questionnaire. The questionnaire was filled by 12 teachers from 10 schools, three of them being female teachers and 9 male teachers. Two of them were Mathematics teachers who had their qualification in Mathematics. The 10 Science teachers from this sample had their qualification in Biology and Chemistry (2) or Biology (7) or Physics(1)

DESCRIPTION OF THE SETTING

For our study, we selected the Gadchiroli district of Maharashtra. There is no rail route within the district. Hence, for conveyance, one has to rely on the State transport or private company buses along the main road connecting Tehsils, black-yellow Tracks cramped with passengers connecting major towns, and the one's own private vehicles for further interior. As one goes from the north to the south of the district, there is lush green forest on either side and small hamlets interspersed and schools on the way. The district has a network Zilla Parishad primary school in every village and secondary school at Tehsil place, the Ashram schools run by Government and Public Private Partnership (affiliated to NGOs). There are private English medium schools. The district is dominated by the Gond and Madia communities, and additionally Halbi community who speak Gondi, Madia and Halbi language respectively. Most of them live in hamlets in the interior and send their children to residential schools, as far as 10 to 40 km away. There are Bengali speaking Namoshudra who migrated here from Bangladesh in the 70's (they get ST status in the state of West Bengal but fall under Open category in Maharashtra) and Marathi speaking Schedules castes, who are relatively in better economic position than the communities described above. These Marathi and Bengali speaking communities usually settle near the market places and their children attend the nearby school as day scholars.

Typical Madia, Gond, Halbi households carry out agriculture in a traditional fashion. They grow enough crops for their own requirements. Some may grow additional vegetables or cultivate an additional crop and rely on forest for their needs. In addition, they work together collecting Tendu Patta and Mahua flowers/fruits during the respective blossom season. While the former gets them cash, the latter is fermented to prepare alcoholic beverages for households. Oil is extracted from Mahua fruits. Some self-help groups are promoting other uses of dried Mahua flowers and fruits to make healthy snacks. Very few villages have both phone or internet networks available (mostly those along the roads connecting tehsils).

While each village has a Primary school, the children have to go to the nearest town for secondary school. Most of the children take admission in residential schools with three brief vacations during Pola (August), Diwali (October / November) and Holi (February / March) apart from the Summer vacation (April - June). A typical day in a residential school starts at 5 am in the morning, lunch at around 10 am, school starts at 11 am with an assembly time and ends at 5 pm. After this, students have free time on the playground for an hour and a half and then gather for assembly near their respective hostel (separate for girls and boys) followed by dinner.

FINDINGS

In this article we will highlight some findings, through excerpts from the survey responses and interviews. The sample of schools surveyed covered all the school types mentioned in the description above. Teachers were asked to select topics in Science and Mathematics that students found difficult to grasp and were asked to elaborate on the general classroom challenges while teaching students from tribal regions in general, those during the pandemic and after reopening of school, post pandemic. Principals or school authorities were interviewed to know more about the students' family background and challenges during the pandemic, and the field notes from interactions with students about how they spent their time when schools were closed during pandemic.

In the following we give an overview of our findings. The quotes given below are translated, paraphrased in some places, not verbatim.

Pre pandemic challenges

Most of these students in the region surveyed lacked a conducive environment or adequate support from home. A teenage student is expected to work during the busy periods of the year, governed by the farming cycle, which leads to irregular attendance. As a teacher told in an interview,

> "The schools start around 26th June every year but not all students return to school. Some return a couple of weeks later as they are helping their family on paddy fields. Same thing happens when they go on brief vacation during the Pola festival (that is time to sow saplings)."

Further, the medium of instruction (Marathi) is not the same as their home language. Students find it difficult to catch up with the formal Marathi.

Textbooks lack local context as one Science teacher writes,

> "The examples given in the book are not known to children or could be shown to them in rural areas. Students are not acquainted with *idli*, which is given as an example of fermentation in textbooks. But if we give the example of Ambil, a local food made by fermenting rice, they will understand it better."

When asked about topics students find difficult to grasp, a biology teacher notes, "Students find it difficult to understand the classification of the animal and plant world"

This observation by the teacher is significant, given the fact that these students come from an environment providing ample opportunities to see this concept 'in action' in their life outside school. Thus, this disconnect with textbooks and curriculum is not merely a case of lack of appropriate real life examples or lack of attention/effort from the students. Additionally, as a teacher who was keen on situating the examples in local experiences pointed out, such efforts lead to lagging behind in syllabus which is then questioned by the authority.

During pandemic

About the life of these students during the pandemic when schools were closed, a teacher writes,

> "There is no academic environment at home. Most of the students got tied up to farming and girls to household chores. It was not possible to have online classes in our region. Students have forgotten basic reading and writing skills."

Director of a school pointed out,

> "A typical household has an ample amount of rice stocked but not as much dal and arrangements for other vegetables. 4-5 children, who are otherwise at school for most of the year, were added to members of the household, and hence there was a sudden crunch of resources. It was natural that children would be expected to to help (to forage in the forest)"

While interacting with students, almost everyone spoke about working on farms and exploring nature. When students, who are now in grade eleven, were asked if they had some concession from work for being in 10 standard, which is a board exam. The class instantly replied in one voice, 'No!'.

One of the researchers had heard a mention of the word 'Jeru' that some students found on the field. Following is a recollection of one of the researchers as narrated during the debriefing session. The researcher is describing their experience with the students of ninth grade.

> "I asked the ninth grade students about 'Jeru'. Students jumped to describe it to me, they told me how it sticks on you and sucks the blood. Not just that they also told how to save oneself if it bites. I guessed the animal they were talking about. It's called Leech in English.

> I recalled having survived my biology lessons without ever seeing one, by memorizing some bullet points."

This instance shows one example where students' lived experiences have potential to enrich their classroom learning. While relating the textbook content to the students' experiences, they show fewer occasions of distractions, compared to other means of teaching, like teaching aid or use of experiments (Ramdas, J. & Kulkarni, V. 1982). But this kind of flexibility to allow teachers to customize textbook content as per local context is sadly missing in the present educational discourse.

Post pandemic challenges

During the closure of school due to the pandemic students did not have access to any form of academic material beyond textbooks. One of the Mathematics teacher writes,

> "Students from class 8 have directly come to class 10, without knowing anything about class 9. The online education during the pandemic has not happened at all due to network issues or financial conditions."

Some teachers also said, 'Children are lacking concentration in studies' after they return to school, but this they will overcome with time. There is a learning loss and students are promoted to next academic year. As a principal of the school state,

> "Teachers are wondering if they should cover the syllabus of the previous year or to teach the current syllabus.."

This concern was also expressed by one of the teachers, who said,

> "Don't understand if we should focus on clarifying the concepts or finishing the syllabus of the present year."

DISCUSSION

The pre-pandemic classroom challenges range from lack of a conducive environment at home and family support leading to irregular attendance, language barriers to inequity in resources. The situation is further aggravated by the pandemic and subsequent closure of school. While students are battling learning loss, lack of concentration, learning deficit, teachers on the other hand are perplexed whether to focus on clarifying the concepts or yield to the pressure of completing the syllabus forcing the children to rote learning. These classroom challenges are here to stay even after the schools begin.

During the pandemic months, the students in this region worked in the field, and learned new out-of-school skills, while closely observing nature. While on one hand students emphasized their proximity to nature, a Science teacher on the other hand pointed out they find topics related to nature difficult to grasp. As pointed out by some Science teachers, the textbooks and the classroom curriculum/discourse dictated by it, are not situated in students' experiences. Students bring along with them to the classroom, their experiential and cultural capital. These are often undervalued or not touched upon in the classroom discourse. Also some of these experiences which do not align with the scientific discourse can lead to alternate conceptions that are left unanswered. Further their socio-cultural background being distinct from the mainstream, they often lack the prior experience which the textbooks (dictated by mainstream culture) assumes.

It can be easily argued that there is a need to design classroom discourse that connects to the lived experiences of the learners. Taking cognisance of their experiential and cultural capital

(Ladson-Billings G.,1995; Gay, 2002) will give a different perspective, while addressing both the pre and post-pandemic classroom challenges. This can be done with the help of the teachers teaching in this region who are sensitive towards this need. These teachers can then work closely with researchers to design a curriculum with appropriate interventions to make the discourse responsive. Which can be used to orient other teachers (Robertson, 2020; Ashley L. White, 2022) and facilitate development of STEM resources in future (Sanders, 2021).

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CULTIVATING THE EPISTEMIC CLIMATE OF LARGE ENROLLMENT INTRODUCTORY BIOLOGY CLASS WITH THE USE OF THE FIVE CORE CONCEPTS OF BIOLOGY

Kyriaki Chatzikyriakidou1, a, * Melissa McCartney1, 2, a, #

[1]STEM Transformation Institute, Florida International University, Miami, Florida, United States of America

[2]Department of Biological Sciences, Florida International University, Miami, Florida, United States of America

[a] she/her/hers

[*] kchatzik@fiu.edu , [#] mmccartn@fiu.edu

The potential of implementing the five Core Concepts-activities could offer the ground for reforms in the current large enrollment biology courses. There is an urgent need to develop instructional approaches that can provide integrated knowledge (content, procedural, and epistemic) to undergraduate biology students. The aim of this study is to describe the potential effect of student analyzing introductory biology topics with the use of the 5CCs of Biology (5CCs), on their epistemic knowledge. Preliminary (n <40) implementations of a 5CCs-activity in a large enrollment biology course showed that learning biology content with the 5CCs significantly improved student conceptual understanding. Furthermore, a positive correlation between conceptual understanding and epistemological beliefs was found to be significant. We invite further investigation in the relationship between biology students' conceptual understanding and epistemic beliefs in order to continue the initial efforts taken towards improving undergraduate biology education.

INTRODUCTION

Each classroom has its own epistemic climate fostered by its main instructional activities and the type of notions these offer to students about construction of knowledge. In a recent study, hypothesizing that the classroom climate perceptions are indeed an important factor in student epistemology development, differences were found when the same instructor taught a traditional lecture-based section, and a constructivist-based section of organic chemistry (Barger et al., 2018). Two main findings were made from this study: 1. student perceptions of a complex learning environment predicted changes in their epistemology, and 2. student initial epistemological beliefs predicted how they perceived the classroom environment (Barger et al., 2018). These findings are not surprising considering the fundamentals of epistemological framing supporting that the physical cues of a class, along with student prior experiences and knowledge, inform those epistemological resources that the student finds appropriate to use within a specific class (context).

An epistemologically reformed course would look like a place where students are supported towards building their own network of coherent and sensible ideas about the world and about their learning process (Berland, et al., 2015). One way to introduce introductory biology students to holistic thinking about biology is to teach them the 5 Core Concepts of biology (5CCs; Evolution, Structure and Function, Information Flow, Exchange, and Storage, Pathways of Transformation of Energy and Matter, and Systems). The 5CCs (Table 1) provide a succinct conceptual framework, describing all potential biology knowledge summarized in five biological scales (molecular, cellular, organismal, population, and ecology) that dictate each natural biological phenomenon (American Association for the Advancement of Science - AAAS, 2011). Russ (2014) has previously argued that students need to negotiate scientific content and construct knowledge within a context informed by their past experiences and knowledge, in order to advance their epistemological beliefs. Understanding that every biological process or phenomenon can be interpreted through five different perspectives, as suggested by the 5CCs, could help students improve their conceptual understanding as well as shape students' beliefs and attitudes for their discipline.

Core Concept	Main description
1. Evolution (EV)	The diversity of life evolved over time by processes of mutation, selection, and genetic change.
2. Structure and function (SF)	Basic units of structure define the function of all living things.
3. Information flow, exchange, and storage (IFES)	The growth and behavior of organisms are activated through the expression of genetic information in context.
4. Pathways and transformations of energy and matter (PTEM)	Biological systems grow and change by processes based upon chemical transformation pathways and are governed by the laws of thermodynamics.
5. Systems (SYS)	Living systems are interconnected and interacting.

Table 1: Core concepts outlined in *Vision and Change* report.

Results from a meta-analysis which measured student epistemologies either with the Colorado Learning Attitudes about Science Survey (CLASS) or Maryland Physics Expectations Survey (MPEX) surveys, found that teaching method was a significant predictor in shifting student's beliefs (Madsen & McKagan, 2015). Furthermore, the authors mentioned a pattern between teaching method, class size and student population, although non-significant. Large positive shifts were seen in courses with small class size, explicit focus on model building and taught to non-science majors (Madsen & McKagan, 2015). Relevant findings have been reported in biology education lab-based curricula. For example, AIM-Bio students were found to have gains in their nature of science understanding (Hester et al., 2018) and C.R.E.A.T.E. students significantly shifted some of their epistemological beliefs (Gottesman & Hoskins, 2013).

These findings refer to freshmen in small size classes with explicit teaching of scientific method skills. Since the first publication of *Vision and Change*, effort has been put into developing conceptual frameworks that could be easily adapted to various course syllabi (Brownell et al., 2014; Cary & Branchaw, 2017) and large enrollment introductory biology courses. Using these frameworks, the Biology Core Concept Instrument (BCCI) tool was specifically designed to measure first-year students' ability to identify and describe concepts represented in biological phenomena (Cary & Branchaw, 2019). More recently, we have developed a 5CCs lesson plan with the aim to advance student science process skills, such as analyzing primary scientific literature (PSL) while using the 5CCs (Chatzikyriakidou et al., 2021a). While biology education researchers continue to develop 5CCs-related activities and surveys that can be used to measure student understanding of the 5CCs (Branchaw et al., 2020), there is very little literature discussing what students learn when they are taught with the 5CCs or how they might be actually using the 5CCs to learn biology in class (Chatzikyriakidou et al., 2021b).

The aim of this study is to describe the potential effect of student analyzing introductory biology topics with the use of the 5CCs of Biology (5CCs), on their epistemic knowledge. Epistemological beliefs have been found significantly correlated to students' conceptual change when learning evolution theory (Borgerding et al., 2017) as well as physics students conceptual gain, both at the beginning and end of the semester (Perkins et al., 2005; Coletta & Philips, 2010). Similarly to these studies, we hypothesized that there would be a positive relationship between student 5CCs understanding and science epistemology, and we present preliminary data to explore the relationship between introductory biology students BCCI and MBEX scores.

METHODS

The Biology Core Concept Instruments (BCCI).

The BCCI survey (Cary & Branchaw, 2019) is an easy-to-use assessment tool designed to evaluate biology student 5CCs understanding. The survey includes definitions of all 5CCs, followed by short narratives of biological phenomena. Students read the narratives and identify those CCs they can recognize. The first narrative (used in this study) of the BCCIs tool is about Recombinant Humulin production and asks students to identify the core concepts: IFES, SF, and PTEM (Table 1).

Maryland's Biology Expectations Survey (MBEX).

MBEX was designed to measure students' epistemological beliefs about biology knowledge and biology learning in a reformed lower-level organismal biology course that integrated multidisciplinary concepts in its syllabus (Hall, 2013). It is composed of 32 Likert-scale statements, separated into four clusters: I) Facts v. Principles, II) Independence v. Authority, III) Interdisciplinary Perspectives v. Silo Maintenance, and IV) Connected v. Isolated.

Since this survey has been used only in interdisciplinary biology classes, we conducted exploratory (EFA, *n*=318) and confirmatory (CFA, *n*=211) factor analyses with lecture-based introductory biology student responses and resolved a different four-factor structure of the questionnaire: a) Interdisciplinary knowledge, b) Application of interdisciplinary knowledge, c) Real-world connections, and d) Learning facts v. principles in class. This new questionnaire structure was used for comparative analysis between the two groups of introductory biology students presented in this manuscript.

Introductory biology students.

There were two General Biology I sections: an experimental section (*n* = 37) and a control section (*n* = 31). The experimental section had a semester-long experience of analyzing three course topics: *Aquaporins*, *Aerobic respiration* and DNA *transcription* with the use of the 5CCs (Chatzikyriakidou et al., 2021b), while the control section did not engage with the 5CCs. In addition, at the beginning of the semester, and prior to any 5CCs activity, we asked students to rank their familiarity with each of the 5CCs on a percentage scale (0-100%). In order to gather accurate self-reported data, no description about the 5CCs was provided other than the full name of each core concept. Only data of students who consented to participate in this study are shown.

BCCI scores were calculated as the percentage of correct answers out of the total 20 questions of the instrument. MBEX scores were calculated as suggested by Hall (2013). Significance of correlation (Pearson *r*) between the two scores was calculated for each group of the study. ANOVA was used to test for significant differences in student scores. All analyses were conducted in R 4.0.0 (2021).

RESULTS AND DISCUSSION

Comparing the two introductory biology sections, we found that students who engaged in the 5CCs activities scored significantly ($p < 0.05$) higher than the students of the control group and the number of students who answered at least half of the 20 questions correctly was twice higher than the number of students in the control group. The Recombinant Humulin production narrative targets students' conceptual understanding of the CCs: SF, IFES, and PTEM (Table 1). Based on the self-reported prior knowledge of these concepts, the control group reported higher familiarity with all three concepts as compared to the 5CCs group, with 29%-49% and 17%-29% respectively. To the best of our knowledge there are no other records of BCCI scores in the literature, so these findings are promising for increasing student understanding of the 5CCs with regular in-class activities.

Regarding student epistemological beliefs, no significant differences were found between the two groups of students, with a range of scores between 23 and 58 points for the control group and between 24 and 56 points for the 5CCs group. An absolute expert-like (based on strongly agree/strongly disagree choices) score, based on the 11 MBEX items that were given to students, would total 41 points. However, due to the Likert-type 6-point scale an expert-like score could deviate between 35 and 46 points. These limits of the MBEX score deviation were used to select the subgroup of students expressing an overall sophisticated epistemological profile, while those with a lower or a higher MBEX score were excluded from analysis. Figure 1 shows those students who had both a sophisticated epistemological profile and a BCCI score of at least 8/20 correct answers, resulting in the 5CCs and control subgroups of 14 and 15 students respectively. Ideally, we would select students with a minimum of 10/20 BCCI score, however the small sample size did not allow for such selection.

In the subgroups of selected students (Figure 1) there were significant ($p < 0.05$) and positive correlations between their MBEX and BCCI scores of 88.2% and 89.6% for the 5CCs and control groups respectively. Considering that students' scores were selected at the end of the semester, this finding may be attributed to a real relationship between conceptual understanding and science epistemological beliefs. In addition, no significant correlations were seen for either of the two groups of students, for those with lower or higher BCCI and MBEX scores than the selected ones. This finding implies a correlation between conceptual understanding and sophisticated epistemological beliefs. However without a pre-MBEX score at the beginning of the semester, we cannot conclude on the effect of the specific 5CCs activity, on advancing student epistemological beliefs.

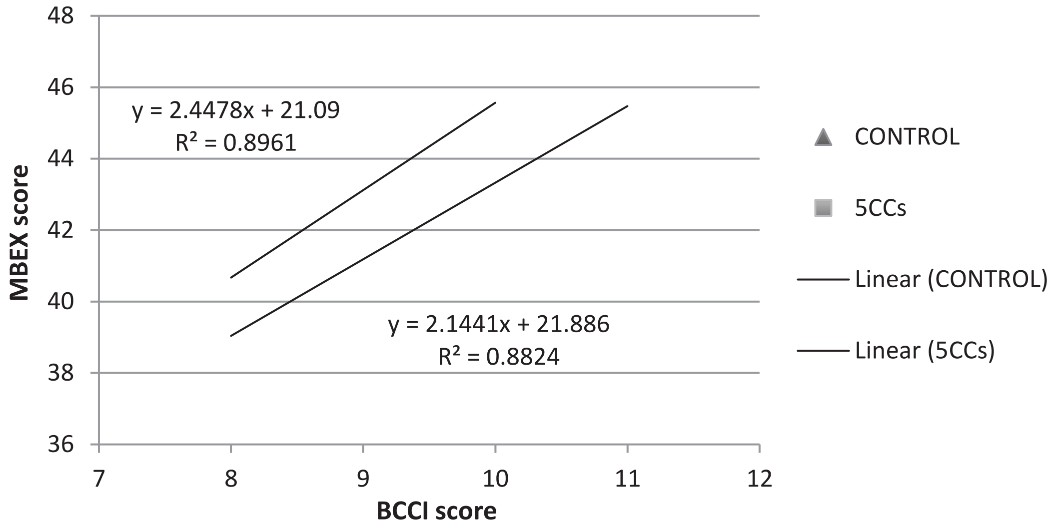

Figure 1: Correlation values of introductory biology student BCCI and MBEX scores for the 5CCs and control groups. Pearson *r* correlations were significant ($p < 0.05$) for both groups. During an academic semester, the 5CCs group of students completed three analysis of biological phenomena with the use of the 5CCs, whereas the control group did not engage with the 5CCs.

CONCLUSION

Every learning environment comes with its own context, thus students will activate epistemic resources based on their prior knowledge on similar learning environments, as well as the current physical and social cues they interpret in the class which they are situated. Additional findings on introductory biology student understanding of the 5CCs are of value for designing epistemologically informed curricula, teaching practices and assessment tools, and consequently help reform undergraduate biology education. Researchers and educators need to understand how portrayals of knowledge in the classroom shape personal epistemology development. We support the argument that integrating the 5CCs in lecture-based curricula would be an important factor setting the appropriate epistemic climate of a classroom, even in large enrollment courses. Through implementation of 5CCs activities, biology instructors could adapt their course learning goals towards conceptual understanding and sense-making of biology knowledge, which would foster alignment of student epistemological beliefs with those of professional scientists. In addition, 5CCs activities can be an innovative teaching material to help educators gauge how well their students understand the biological concepts covered in the course material.

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EXPLORING STATUS OF SCIENCE EDUCATION IN INDIAN RURAL CLASSROOM: A STUDY OF EASTERN DISTRICTS OF UTTAR PRADESH

Kajal[1, a, !] and Sunita Singh[1, a, #]

[1]Department of Education, University of Delhi, New Delhi, India.

[a]she/her/hers

[!]kajalverma7023@gmail.com, [#]nitivasudev@gmail.com

The issue of equity and accessibility are considerable matters to be of concern in our education system. These issues are more prevalent in the realm of science education as the existing discourse concludes on disadvantaged groups (for instance girls, learners with disabilities (VI), those who belong to remote/rural/tribal areas) in science. Hence, intersectionality among these may lead to exclusion of many learners from meaningful learning. For instance, girls and learners with VI in rural/remote areas of India are more prone to this vulnerability. Thus, taking the stance of democratization of science education to advocate the principle of science for all, the present paper critically examines issues and challenges in science education in rural Indian classrooms and how teachers and students are coping with it. For this, the researchers visited GHS, GGIC and GIC located in the eastern districts of Uttar Pradesh, India, and the data was collected from students, and teachers via semi-structured interviews. Findings reveals some serious concerns such as lack of science teachers and resources, gendered subject choices (in 10+2), learners with VI do not opt for science, narrow understanding of career prospects in science among female learners, teachers' conception of the nature of science as a superficial, traditional medium of teaching. Moreover, due to the COVID-19 pandemic, the education of these students has been deeply compromised. The study critically examines distinct factors that hinder the entry of many female learners and VI learners into the field of science. Finally, this paper stands to incorporate some serious concerns and recommendations & policy reformations on the existing situation including encouraging science for all, immediate recruitment of teachers, releasing funds to improve lab facilities, etc.

Keywords: Science Education, Science in Rural India, Equity, Female and VI learners, STEM Education, Science Education Policy

INTRODUCTION

Science has a special place in Indian school curriculum and has become extremely popular among Indian students. The report of KMPG in India and Google (Khaitan, et.al. 2017) suggests that there has been an increase in enrolment of students opting for science at secondary level. Despite this, the issue of equity and accessibility are considerable matters of concern in our education system. These issues are more prevalent in the realm of science education, especially in rural areas in India which also lack the basic infrastructure for teaching learning in the classroom. Many rural children are not exposed to the diverse ways in which STEM is practiced in the world(Harris & Hodges, 2018). As the existing science curriculum conformed completely with the criteria of 'pure' theoretical knowledge laid down by the elite which leads to demanding a more democratic environment within the classroom (Rampal, 1992).

The Gender perspective

Numerous researches confirms that subject choices are more being gendered in our education system, especially when it comes to science and it is not considered to be favourable for girls to pursue in order to establish a career further (Bal, 2004). These gendered subject choices are most prevalent further if female learners choose to opt for science, medical stream considered to be appropriate for them. The stereotypical ideology has various arguments such as science is logical and analytical hence female learners cannot do it, the stereotypical beliefs conclude female learners to be emotional and less logical. This is not just belief instead an ideology in our patriarchal society across the world. The socioeconomic conditions of Indian society women's education and STEM education and careers are more complex (Amirtham & Kumar, 2021). Women are hindered in choosing science and technology courses, especially the physical sciences and mathematics that are considered suitable for men, because conventional thinking has been internalized and passed on Generations (Indian National Science Academy, 2004). Brooks explores the relationship between gender, power, and academia, distance among instructional equality and the version of equality and the truth of sexism in academia. She additionally argues that "there may be a clean contradiction among the liberal ideology and egalitarian dreams of academia, and the truth of instructional careers competing in male-ruled hierarchies." result in segregation. Sexism and racism are pervasive in opposition to ladies to defend male privileges (books 1997 as cited by (Ru & Chanana, 2003). "Science for All Americans" is a science that helps students collaborate with others to use science and technology wisely and become informed citizens who can solve many of the global problems facing humanity today. Includes educational discussions. It is noteworthy how such documents present science and technology as benign. (Rutherford & Ahlgren, 1990; Irwin & Wynne, 1996 as cited by Roth & Desautels, 2004). Despite the fact that Indian women are not seen as incapable of conducting science and engineering, female presence in these disciplines is limited: the generic scientist is still seen as male.

Learners with VI[2] in science

Learners with VI struggle more to pursue a career in science as (Gupta & Singh, 2013) demonstrated that Indian schools for learners with VI are quite poor because of the lack of specially trained teachers and suitable equipment and instructional material. Study by The Xavier's Resource Centre for the Visually Challenged (XRCVC, 2013) reveals that the level of mathematics and science teaching and learning in India for the blind and low-vision is at a very nascent stage currently. A large number of students tend to drop out of studying these subjects at Class 8 and opt for other subjects such as music, language etc. Although this is an optional choice, over a period of time it has become the default choice due to paucity of services and resources to make these possible and apprehensions amongst students, teachers, and parents alike. (Taraporevala, 2011), argued that even after given the high aspiration of STEM (Science, Technology, Engineering, and Mathematics) careers in our country, the lack of access to the same for blind and low vision persons creates an increased sidelining and marginalization of the group from the mainstream. (Palan, 2020) mentioned that a student wanted to opt for science at senior secondary level but the school refused, so she opted for humanities. Besides lack of access to the same mathematics and science curriculum as available to sighted students, another factor that contributed to the high enrolment of students with a visual impairment in Arts, Humanities and Social Sciences was the limited subject options offered to them.

[2] VI- Visual Impairment (includes both partial and complete blindness)

Initiatives taken by Government of India

Efforts are being made to modify this mindset. For instance, *RAA (Rashtriya Aviskar Abhiyan)* and some of the interventions under RAA for promotion of science are strengthening of school Science and Mathematics laboratories, Science Fair/Exhibition and Talent Search at district level; provision of mathematics and science kits to schools, visit of students to higher educational institutions and learning enhancement of students. Moreover, *National Institution for Transforming India (NITI)* under the Atal Innovation Mission is establishing *Atal Tinkering Laboratories (ATLs)* in schools across India. Further, an amount ofRs. 425.39 crore had been approved for in-service training of science and maths teachers, remedial teaching, provision of science and maths kits, science exhibitions, etc under *Rashtriya Madhyamik Shiksha Abhiyan (RMSA)*. Other than that *STEM* (science, technology, engineering, and mathematics) education, STSE (Science, technology, society and environment) approach, *STEAM* (Science, Technology, Engineering, the Arts and Mathematics) as an educational approach are some other reforms in science education. *Vigyan Jyoti* is a program launched by Department of Science and Technology to bring gender parity in STEM by promoting meritorious female learners at school level. As mentioned above, the government of India has taken many initiatives to bridge this gap, still, these initiatives must be kept in a critical lens as it is not visible on the ground level as it should be.

METHODOLOGY

The present study is qualitative in nature that falls under descriptive research design. Aiming to critically examine the status of science education, the researcher has visited Government high schools (GHS including GIC and GGIC) located in the eastern districts i.e., Varanasi, PratapGarh, Allahabad and Mirzapur of Uttar Pradesh, India. The schools were selected through multistage sampling criteria. The data were collected from 20 schools (five from each district that includes 12 GHS and 8 were GIC & GGIC) and through field observation (non-participatory observation), semi-structured interviews of teachers as well as students. Around 50 students (due to COVID-19 not many students were available in the school) and 11 teachers were interviewed and their responses then thematically analysed. This study aims to unfold the issues and challenges in the realm of science and science education in rural regions of India.

RESEARCH QUESTIONS

- What is the status of science education in the eastern districts of Uttar Pradesh, India?
- Is science education being equally accessible for all learners?
- How learning science is different/ difficult for learners belonging to VI and female learners?
- How the COVID-19 pandemic has influenced the nature science classroom discourse?

OBJECTIVE OF THE STUDY

1. To explore the status of science education in rural Indian classrooms.
2. To unfold the issues and challenges (specific to female and learners with VI) in science education at the ground level and scope of improvement in eastern districts of Uttar Pradesh, India.

FINDINGS

In this regard, researcher presents the ground realities originated from collected data, that is:

- Maximum visited schools didn't have science and mathematics teachers at the secondary level (8 out of 12).
- Dispiritedly, teachers' response to their conception of the nature of science was superficial and the pedagogical approach was limited to the traditional medium of teaching; majorly due to lack of resources.
- Maximum GGIC do not offer mathematics or non-medical subjects at 10+2 level, therefore many female students opt for biology (medical stream) and those want to study math have to move to other schools.
- Girls were less to pursue science as compared to boys and had a narrow understanding of career prospects in the discipline due to limited exposure.
- The popular career options for female learners after 10+2 (those who opt for science) is teaching and they usually opt B.Sc (Home Sci.).

- Learners with VI do not opt for science even after elementary level.
- Apart from that, learners who tend to drop out to pursue a career in science mostly belong to a low socio-economic background and consider it as “difficult”.
- Moreover, due to the COVID-19 pandemic, the education of these students has been deeply compromised. The huge shift to complete offline to a completely online mode of education has influenced the nature of science classroom discourse. Instead of promoting inquiry and exploration, students are encouraged to learn definitions and facts.
- During pandemic, due to the inaccessibility of resources (digital resources), most of the students were forced to indulge in other chores for instance girls in homemaking and boys to work at the construction site,etc.

DISCUSSION

The dearth of teachers and resources:

One of the major concerns is the unavailability of sufficient science and mathematics teachers at schools. It was found that teachers with expertise in language (especially English)/social sciences were teaching science and mathematics at secondary level in most of the schools. Moreover, students at schools of Varanasi verbalized,

> “We don’t have science teacher since the school (GHS RMSA) has been established.”

> “We pay for mathematics and chemistry teachers (GGIC) then only we got to have resource teacher for maths, chemistry, and biology.”

they added, “we rarely go to the science lab and only students in 12th standard are allowed to visit during the practical examination otherwise the science lab tend to close most of the time”

Although all visited schools had a separate science laboratory, however, the condition of the science labs was found similar in all the districts. Whereas, schools of Varanasi and Allahabad districts had better condition (in terms of physical infrastructure) as compared to the schools in PratapGarh and Mirzapur districts.

Pedagogy

Interestingly, among all, the only one visited school in PratapGarh district was found as inspirational as well as resourceful to support inquiry-based science classroom. The science laboratory was found in excellent condition with sufficient material and apparatus. The principal was the science teacher of the school as well and he has been practicing innovative pedagogical techniques to make science more contextualized and enjoyable. According to him,

> “Science should be contextualized according to the cultural background of the learners and pedagogy should be improvised in a way that is relatable for the learner and can develop a curiosity to know.”

For him, a constructive talk on scientific issues relating to social condition of the learners is the best pedagogical practice to learn complex scientific concepts and be able to solve socio-scientific problems. Hence, the preference for a context that supports an argumentative discourse requires consideration of plural narratives of phenomena and a context that allows a discourse to dialogue a discourse that is a natural product of any community and at least consider all members to be, in principle, equal (Duschl & Osborne, 2002). Dialogue thus conceived as the value of praxis as a form of student-centred learning and teaching (Breunig, 2009). The teacher and the students have won various prizes at district as well as at state-level in various competitions including events in science with a huge participation of female learners. Apart from this, other teachers who were interviewed across all four districts were not found as enthusiastic as him, due to the lack of resources, most of them feels helpless and hence couldn't constitute a conducive environment for doing science. consequently, they tend to focus on the completion of the syllabus, learning proper definitions, emphasis on assimilation of information rather than inquiry.

Accessibility issues in science

The physical barrier: Interestingly most of the girls who were interviewed in Varanasi district, all have opted for science, and that including biology and mathematics but most of them tend to switch it to humanities. According to their responses, many of them said they would like to do the job after intermediate (12th standard) in order to financially support their family. Moreover, some remarks were showing diminished exposure of female students towards career prospects in science, such as,

> "Many of the girls will drop out of school due to school fees and other charges because parents who have 3-4 children, struggle to submit the charges by the school."

> "I would like to do MBBS but I will do it from distance mode, and parallelly I will do a job in order financially support my family"

However, when asked to male students, they expressed,

> "After 12th, I will move to city. Probably Delhi. then I will give JEE exambut I will also enrol myself in B.Sc if not able to clear and then further M.Sc"

> "I want to do polytechnic…. (Which course?) …civil engineering"

It can be observed that even after belonging to same context and age cohort, male students were much aware of various career prospects as compared to the female students. However, at such an initial stage, these students were not supposed to be aware of various possibilities and opportunities at school, still an overt analysis of responses describes the educational exposure of different gender in a similar context. Furthermore, government schools are not supposed to take any charge except board examination fees, still these students were asked to submit charges for resource person, schoolevents, textbooks, etc.

Learners with VI in science: Learners with VI are no different from their sighted counterparts. Instead, the difference lies, in the ways adopted by teachers to enable learning by these learners. It was intensely grilled into the learners with VI that science was not for them. Most of the learners with VI learn science at the elementary level only as a formality and only a few students pursue it further in India (Palan, 2020 & XRCVC, 2013). Learners with VI require suitable pedagogical techniques that work with them, that tap their tactile and hearing sense optimally so that they can overcome their inability to learn using visualsense. As the researchers were not able to contact any VI student, thus, asked teachers about their perception, they shared,

> "They have less interest in science, one is, they find it difficult and maybebecause it is compulsory only up to elementary level."

> "They choose art, music or other subject because that is easier for them tounderstand and to score good"

Career in STEM: During the visit it was found that many GGIC across all four districts do not offer Math (or non-medical subjects) at 10+2 level, therefore female learners have to opt for biology (medical stream with Home Science), those who wish to opt for math (non-medical stream) have to move to other school. Which many at times considered not feasible for female learners (moving from girls' school to Co-Ed school especially in rural areas), thus hinders entry of many female learners to establish a career in STEM. On a discussion with a teacher in GGIC (Allahabad) reveal,

> "our school do not offer Math's at 10+2. For instance, we have 600 students in 9-10th and more than 50% (more than 300) opt for humanities, remaining of them op tfor science (medical stream) but those who wish to study math, have to move to other schools."

This above situation was similar in all four districts. In a nutshell, limited offered subject at school can be considered as a major factor that inhibits women to pursue a career in science (or STEM). In addition, the popular career choices among female learners who opt science was teaching (in science).

The quality aspect: The quality of science education is influenced by the pedagogy and the presentation of the content in the textbook. According to the responses, most of the students consider science as "difficult" because they struggle with the language (terminologies) of the content. Moreover, the examples and applications mentioned in the textbook could be general, and to make more relatable pedagogical interventions are imperative to be done. In other words, the reason why girls were opting for other subjects or dropping out from school, is, poor quality of education in government schools. In addition, subject like science then requires further guidance, to which student tend to join coaching classes, which again more feasible for boys in rural areas than girls.

INFLUENCE OF COVID-19 ON THE NATURE OF SCIENCE CLASSROOM DISCOURSE

Due to pandemic, a complete shift from offline to online mode of education hasopted. However, it was not favourable for many learners, especially learners in rural/remote areas that belong to low socio-economic backgrounds. Students and teachers' perceptions on the influence of online mode of education in science classrooms reveal that:

Some responses of teachers,

> "It is not favourable for learners with weaker-economic section".
>
> "I found that being practical using their nearby things make it easier to teach about the topic and them to understand, but without face-to-face interaction, it is difficult for them to understand completely."

Some responses of students,

> "Many of my scientific concepts are still not clear. Learning online is a bit complicated for me. For a proper understanding, I need someone who is teaching me face to face. Online classes are helpful but offline classes are better."
>
> "Science can be taught online but when it comes to experimental explanation there would be difficulty in understanding, lack of space, and lack of a learning environment at home is not supportive to understand scientific concepts."

In Varanasi schools, for instance, with a strength of 28 students, only three-four students were able to join the virtual classes, and that too were accessible for boys only. Those who were able to access virtual classes were asked to learn and record definition and send it to the teachers. In essence, the virtual classes were lacking interaction as well as the scope of inquiry. The nature of virtual science classroom discourse was limited to product rather than process.

CONCLUSION AND SUGGESTIONS

Science education for practice, conflict and opposition opens up the possibility of critical democratic participation, which includes a fundamental shift in current science curriculum policy and various types of scientific knowledge. Includes production and use of (Levinson, 2010). In today's environment, the STEM sector plays an important role in revitalizing the economy and improving welfare. Therefore, Gender Equality in Medicine and Health Sciences and elsewhere, is a priority, not a luxury (Butcher, 2011).

This paper incorporates some serious concerns and recommendations & policy reformations on the behalf of the existing situation of science education including

At policy level: Encouraging science for all

For which girls those who wish to, should be encouraged to pursue a career in science with adequate counselling regarding career prospects. Learners with disabilities and especially those learners with visual impairment have narrow career opportunities. Moreover, even at the secondary level rarely do they opt for science. Therefore, provisions should be made to encourage these learners to pursue it especially those who wish to. Thus, this indicates qualified science teachers are equipped with inclusive pedagogy and resources including assistive technologies.

At the state level: adequate implementation of various schemes on science education

As mentioned about the initiatives taken by the government to support science education, however, many of them are not properly implemented at ground level, for instance, immediate recruitment of science and mathematics teachers, distribution of textbooks, releasing funds to improve lab facilities, etc.

At school level: Science and digital mode of education

From the responses of teachers and students, it can be concluded that education was not feasible for everyone during the lockdown. They suggest that schools shall now be open for remedial teaching especially for those who don’t have access to it. Moreover, students shouldbe asked to practice some practical portion of the subject in schools which is not feasible at home. However, the researcher also suggests that teachers and students shall be aware of different digital learning platforms initiated by the government of India such as e-pathshala, virtual labs, 34DTH channels (SWAYAM PRABHA), PMeVIDYA, etc.

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MATHEMATICS ACTIVITIES FOR IMPROVED LEARNING, ATTITUDES, AND INTERDISCIPLINARY TRANSFER

Ameya S. Kolarkar

Florida State University, Tallahassee, Florida, USA

he/his/तो

akolarkar@fsu.edu

Through the concept of affective draw, we attempt to address three issues that non-maths-major undergraduate students face the world over: a) fear and anxiety leading to a lack of confidence and motivation, b) value of learning the material, and c) the lack of transfer of acquired skills and knowledge to other environments and disciplines. Through these carefully crafted activities in maths service courses, we offered students a set of problems embedded within a continued storyline and real-life applications. Student and teacher feedback indicated not only higher levels of enjoyment and engagement, but preliminary results confirmed better learning and investment in the value of learning maths (attitude shift). This paper discusses methods and some initial results.

INTRODUCTION

In this paper, we describe some transformative elements introduced and implemented in service courses for non-maths-majors in a large R1 (research intensive) institution in the United States of America (USA) to improve students' attitudes towards mathematics and lead to better learning outcomes. The common attitude towards maths is that of fear and anxiety (Luttenberger, Wimmer, & Paechter, 2018) (Daches Cohen, Korem, & Rubinsten, 2021). There is also widespread confusion about its value to students' majors and interests, and relevance to real life (WEE TIONG SEAH, 2016) (Philip Clarkson, 2016) (Fan (范良火), 2021). Furthermore, even if the student does well in basic mathematics courses, they find it difficult to apply the knowledge and skills acquired in the maths courses to other downstream courses like physics or engineering—known as the *transfer* issue.

Many if not most maths courses are taught as procedures to know and follow without applications to other disciplines of interest to students, or to real life. *Sense-making* is almost entirely missing which leads to difficulties in downstream courses (Gupta & Elby, 2011). Surveys show that students come away thinking that maths is mostly memorizing equations and applying them blindly to problems asked in tests and quizzes.

Another situational factor to consider—in our case at least—is the fact that the service courses are not all taught by mathematicians. These teachers—although experts at teaching the subject matter—are mostly unaware of how the maths applies to other disciplines since they themselves may not have taken courses in those disciplines. Teaching maths in applied situations gives a deeper insight into the workings of the mathematical concepts; these insights are mostly absent for these teachers, in our experience (Anna-Lena Dicke, 2021). For example, in physics 1D motion, velocity and time variables are not *dummy* variables and thus not interchangeable like x and y usually are in mathematics. And in graphing them, the slope has a physical meaning, whereas in basic math, the slope is mostly dimensionless.

Our approach introduces activities that are derived from applications to other disciplines and that draw students in through continued storylines to keep students invested and curious to know what is coming next. This is the *affective draw* (Manu Kapur, 2012)—it not only keeps students interested in the topics at hand but also improves their attitudes towards math as a discipline. They are now thinking about the *good* things associated with the concepts, depending on how much they were personally invested (*affect*ed) in the storyline.

APPROACH AND IMPLEMENTATION

Our approach to address the abovementioned issues is to utilize not just one draw – the applications of the maths concept to their interests/majors/real-life, but another one simultaneously—one that appeals to their feelings and emotions, i.e. *affect*. After all, the students *feel* maths is difficult or irrelevant, so it is only natural to address the feelings part of their humanity. Ultimately it is imperative to find out if the students' attitude towards maths overall as a discipline has changed: Have they started taking more interest in maths or maths-heavy topics? Have they changed their majors?

Preliminary survey data from students reveal that their attitude and confidence improve. We are on track to measure their learning using quiz and test data, as well as following them through downstream courses that have these maths courses as a prerequisite.

Thus far, the courses transformed in this manner are Analytical Trigonometry and Precalculus Algebra, with College Algebra and Calculus 1 coming soon. Applications are taken from physics, engineering, medicine, and also from the other natural sciences, computer science, and technology as applicable. Attempt is made to provide examples from the major disciplines of all the students taking the class, but some applications may take a backseat depending on the size of the class and the number of majors.

The stories take many forms depending on how the mathematical concept can be incorporated in the storyline. Stories usually involve the students themselves and the adventures they go on where they use their maths knowledge for winning a soccer match, finding a missing trophy, wooing a Favourite Person, and so on. In some cases, the stories allude to dependent disciplines that students may take as their downstream courses. For example, Snell's Law is alluded to in a trigonometry-based storyline, but the physics of Snell's Law is not discussed.

THE ACTIVITIES

Activities take place either in the classroom or in the labs. In the lab, the activity is presented to students over Canvas, our Learning Management System (LMS). The Teaching Assistant (TA) introduces the aspects of the activity in her/his own way (consistent with their own identities and personalities) and then the students work in groups as the TA and a Learning Assistant (LA) moves around in the lab ready to help the students through proper questioning strategies. The LAs are trained in such strategies. (Learning Assistants—LAs—are undergraduate students who performed well in a course and come back in later semesters to help students succeed in the course.) Activities are presented in dynamic form on Canvas and are, unfortunately, unable to be published in static, print form. Screenshots of parts of an activity are shown in the figures at the end of this paper.

In a classroom setting, the teacher may use Canvas or other polling software to get students to respond. Groupwork could be a little more challenging in this setting depending on the physical layout of the classroom. Nevertheless, moving around the classroom to help students, although inconvenient, can be done.

Classes and labs during these activities are noisy as students discuss the problems and situations and try to come up with the correct approach to solve the problem. They must understand the situation and determine which concept is applicable, after which they can set up the equations, solve them, and finally make sense of the answers—these are like the notorious and dreaded *word problems* in maths. Students are found talking, laughing, drawing, making hand gestures … in short, enjoying doing the activities!

Gamification is catching on as an effective way to approach today's education, especially for difficult (typically maths-heavy) subjects. In the same spirit, presentations and workshops on this topic are also gamified. Please note that there is a difference between *gamifying* and *gaming* the system—some people use gamifying to mean both, thus negatively portraying the gamification concept. Readers are requested to pay attention to the context. Sometimes 'play' is used to avoid confusion.

DIVERSITY, EQUITY, AND INCLUSION

The activities are chosen to be inclusive of all students to improve their sense of belonging in the class. Studies show that this is important to amplify the success of students, in particular underrepresented ones (Cohen & Garcia, 2008). The story too lets students pick and choose characters that reflect their own identities and mimic their lived experiences. Stereotypes are avoided (e.g., women are portrayed as equally capable mathematicians, detectives, and heroes of the stories as men); Eurocentric viewpoints that are prevalent in the many societies around the world are challenged (e.g., historical mentions and proofs of the *Pythagorean Theorem* in Mesopotamia and other ancient civilizations are presented; Bhaskar's discovery of the *quadratic formula* is mentioned); students are allowed to experiment with their own storylines. We even solicit story continuation ideas from students—some oblige, some are content to see where the story takes them.

Women and underrepresented minorities are well-represented in the graduate student and Learning Assistant populations. This way students see someone 'like them' doing a useful activity that helps them succeed in their own interests, while at the same time making it enjoyable.

RESULTS AND STUDENT RESPONSE

Student response to these redesigned gamified activities is positive. A vast majority of students received the activities with excitement. Our initial student surveys indicate that students were not only enjoying doing the activities in lab or class, but also talking about them outside of class. Some of the student comments are presented below. They said that not only were they finally able to see the application of the maths to their own interest but they also changed their entire attitude towards maths – they could see the conceptual basis of maths, including why maths is the language of STEM, so to speak. Here are a few comments from the students:

> "I realized that math is actually a lot more conceptual than I originally thought!! I was always so overwhelmed by the numbers and equations that I forgot to take a step back and make sure that my approach and final answer were making sense with the information I was given!"

> "I used to be super meticulous … about putting numbers into my calculator and just hoping it would make sense, but now I see math more analytically/conceptually which has definitely helped."

“This course prepared me for physics and I could use it if I ever need to build anything.”

Of the students who did not respond favourably include those who were used to being taught in a specific way and were so far successful using those methods. Most of those methods involved memorization and procedure, which the students mischaracterized as understanding and learning. Much of this is seen through the type of assessments given to the students. If the assessments favour memorization, students who memorize well do well on them. Quick informal interviews of these students reveal the gaps in their understanding, but they still do not want to give up what has worked for them thus far. Another camp of naysayers includes those who say they are paying money for someone to teach them (implying *lecturing*) and they did not sign up for this *active* way of learning. Ultimately, we believe that their attitude will also change as they come across more activities-based learning in their other courses. Indeed, there exists evidence of such transformations in students (Adam J. Castillo, 2022). Sometimes it is simply the concept or storyline that does not jive with the student. For example, some students complained about the soccer activity since they did not know anything about soccer, even though knowledge of soccer rules was not required to complete the maths activity.

Since the newest activities are still underway, and we had to spend time convincing some faculty to let us collect some data, newer data are always coming in. We are using *mixed methods* (both qualitative and quantitative) for this part of the results. One kind of number that the University is interested in is the reduction of the so-called DFW rates (these are the percentages of students per course who drop or withdraw from the course or receive final letter grades of D or F in the US university grading system) which we get from the Institutional Research (IR) Office. Thus far, data from the previous semester shows a drop in the DFW rates of up to 25% in the Analytical Trigonometry course. We are also currently collecting data in downstream courses, mostly physics, and some chemistry and engineering.

However, the DFW data do not actually measure student learning and skills (or transfer skills)—we are collecting evidence on student learning through other means: in-class polling, assessments within the courses, vetted standardized tests, and similar. These are grounded in literature and our efforts will add to the existing literature by measuring present and continued student success via the *affective domain*. Through the Learning Assistant Program, we are also specifically addressing *mis*conceptions (alternatively, preconceived notions or *pre*conceptions) and best ways for guided practice & targeted feedback in the STEM courses; the part about how this was implemented in the classroom and in the activities is beyond the scope of this paper.

CONCLUSIONS AND FUTURE WORK

Initial analysis of the gamified maths activities in some of our basic math courses shows improved students learning of maths concepts and also their attitude towards mathematics. It has reduced the stereotype-driven anxiety of students and has shown to be useful for students from all demographics. Some upcoming studies involve following the students in other courses (maths-heavy downstream courses) and in their major to correlate success to the transformed maths courses. We have connected with physics, engineering, and chemistry teachers to continue to follow the progress of these students in longitudinal studies. Surveys and interviews indicate that students feel more confident going into these courses as a result of the transformations in their basic maths courses.

A critique of this method seems to stem from some teachers not wanting their students to treat everything as *fun* or *story-like* which they feel would be detrimental in a real-world scenario. This is yet to be borne out by evidence; students’ thinking process from our study does not reveal any distractions during complex problem-solving. However, the author is aware of this critique and will attempt to resolve it and determine its validity in future studies.

Acknowledgement

We wish to acknowledge the basic maths teaching faculty and the Associate Chair of the Mathematics Department (responsible for the basic maths teaching efforts) for letting us transform the activities and collect data to measure efficacy and for future support.

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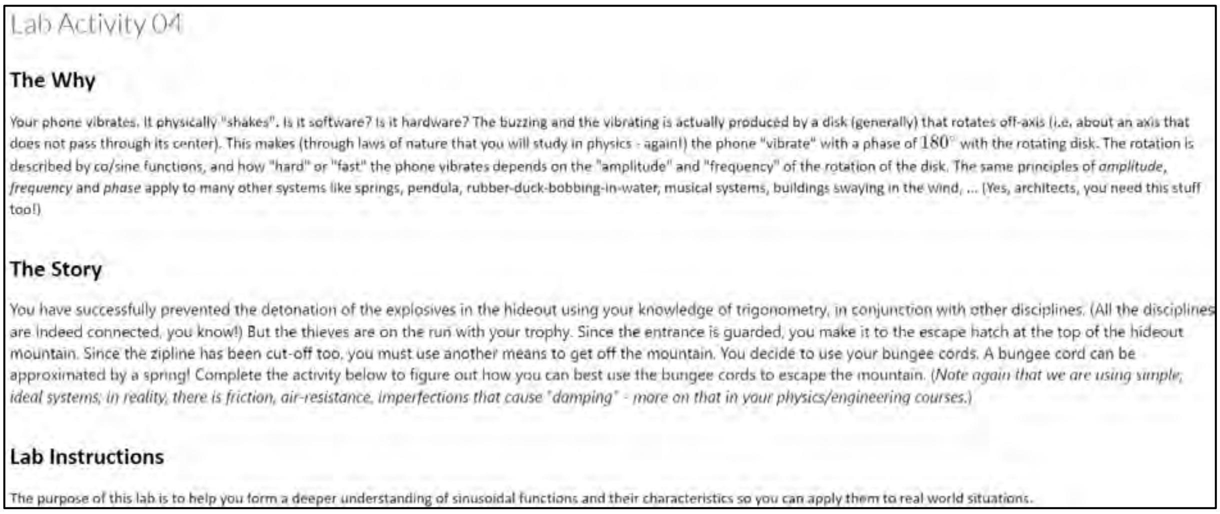
ACTIVITY SCREENSHOTS



Lab Activity 04

The Why

Your phone vibrates. It physically "shakes". Is it software? Is it hardware? The buzzing and the vibrating is actually produced by a disk (generally) that rotates off-axis (i.e. about an axis that does not pass through its center). This makes (through laws of nature that you will study in physics - again!) the phone "vibrate" with a phase of 180° with the rotating disk. The rotation is described by co/sine functions, and how "hard" or "fast" the phone vibrates depends on the "amplitude" and "frequency" of the rotation of the disk. The same principles of *amplitude*, *frequency* and *phase* apply to many other systems like springs, pendula, rubber-duck-bobbing-in-water, musical systems, buildings swaying in the wind, ... (Yes, architects, you need this stuff too!)

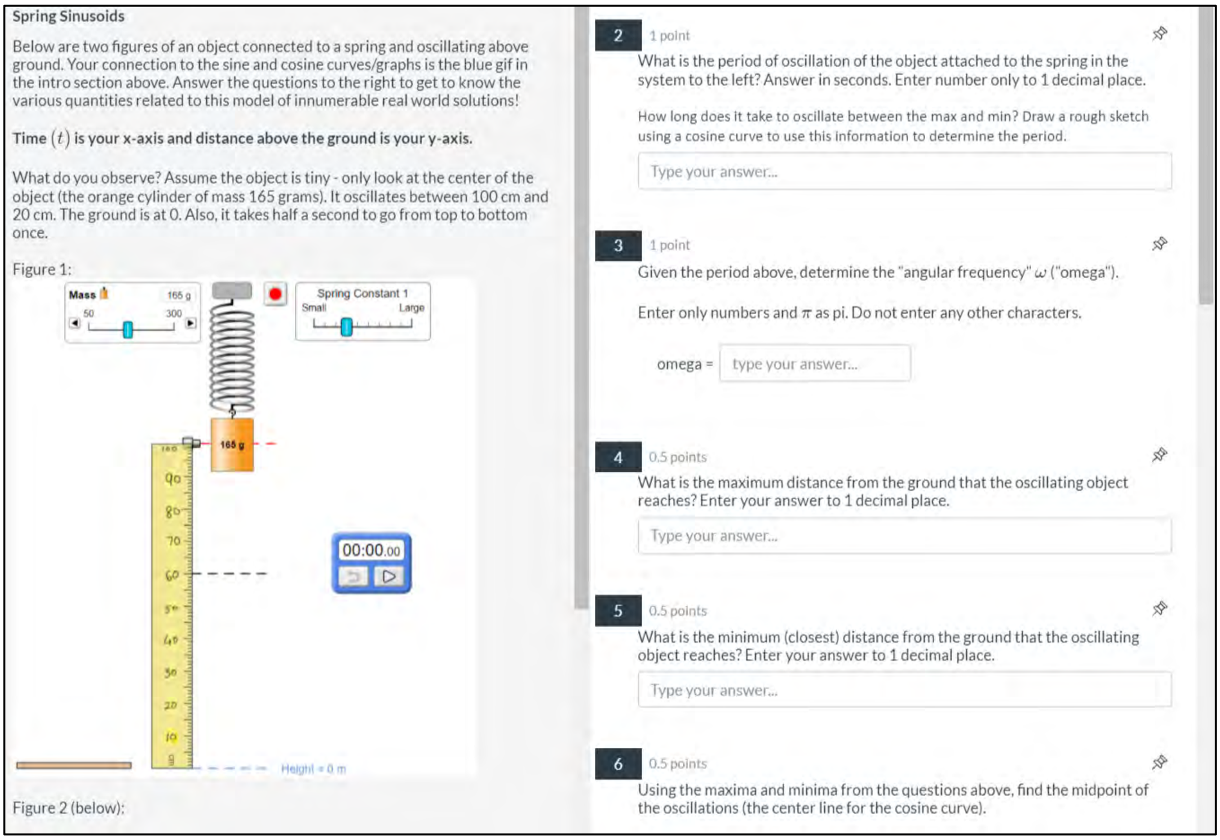
The Story

You have successfully prevented the detonation of the explosives in the hideout using your knowledge of trigonometry, in conjunction with other disciplines. (All the disciplines are indeed connected, you know!) But the thieves are on the run with your trophy. Since the entrance is guarded, you make it to the escape hatch at the top of the hideout mountain. Since the zipline has been cut-off too, you must use another means to get off the mountain. You decide to use your bungee cords. A bungee cord can be approximated by a spring! Complete the activity below to figure out how you can best use the bungee cords to escape the mountain. (*Note again that we are using simple, ideal systems; in reality, there is friction, air-resistance, imperfections that cause "damping" - more on that in your physics/engineering courses.*)

Lab Instructions

The purpose of this lab is to help you form a deeper understanding of sinusoidal functions and their characteristics so you can apply them to real world situations.

Figure 1: Introduction to the activity with an application to real life (cell phone vibration), some connection to their majors, and the continued storyline.



Spring Sinusoids

Below are two figures of an object connected to a spring and oscillating above ground. Your connection to the sine and cosine curves/graphs is the blue gif in the intro section above. Answer the questions to the right to get to know the various quantities related to this model of innumerable real world solutions!

Time (t) is your x-axis and distance above the ground is your y-axis.

What do you observe? Assume the object is tiny - only look at the center of the object (the orange cylinder of mass 165 grams). It oscillates between 100 cm and 20 cm. The ground is at 0. Also, it takes half a second to go from top to bottom once.

Figure 1:

Figure 2 (below):

2 — 1 point

What is the period of oscillation of the object attached to the spring in the system to the left? Answer in seconds. Enter number only to 1 decimal place.

How long does it take to oscillate between the max and min? Draw a rough sketch using a cosine curve to use this information to determine the period.

Type your answer...

3 — 1 point

Given the period above, determine the "angular frequency" ω ("omega").

Enter only numbers and π as pi. Do not enter any other characters.

omega = type your answer...

4 — 0.5 points

What is the maximum distance from the ground that the oscillating object reaches? Enter your answer to 1 decimal place.

Type your answer...

5 — 0.5 points

What is the minimum (closest) distance from the ground that the oscillating object reaches? Enter your answer to 1 decimal place.

Type your answer...

6 — 0.5 points

Using the maxima and minima from the questions above, find the midpoint of the oscillations (the center line for the cosine curve).

Figure 1: The 'bungee cord' from the storyline modeled by a vertical spring-mass system (figure from PhET simulations). Through discussions with their peers and TA/LA in the lab, students were able to solve this problem.

MEREOLOGY FOR STEAM AND EDUCATION RESEARCH 128

A Mani

MIU, Indian Statistical Institute, Kolkata-700108

she/her/hers

Email: amani.rough@isical.ac.in Orcid: https://orcid.org/0000-0002-0880-1035

Mereology is widely applied in STEAM and philosophy. However, serious applications tend to be restricted to specialist groups or the nature of applications is too focused. In addition, methodologies associated do not percolate to school or college-level classroom discourses in a clear way. This is worrying because mereology can be used for effectively understanding concepts, their interrelations, promoting innovative reasoning, and motivating complex directions in engagement in all branches of STEAM (and at all levels). Additionally, it is essential for a proper understanding of compositionality in artificial intelligence (AI) and machine learning (ML), and can be used as a powerful language for describing interactive aspects of learning tools. Further, they can be applied to the problems of evaluation, formalizability of discourse, and student-centric teaching. In this research, the current scenario and related issues are discussed, and possible directions of adoption at relevant levels are proposed.

INTRODUCTION

Mereology is the study of part-whole relations and those closely related to it such as is a part of, is a proper part of, is a whole of, is an integral part of, is an essential part of, is connected with, is in contact with, is disconnected from, is apart from, and approximate part of (these will be hyphenated in what follows to improve readability). Such relations can be found everywhere, and they relate to both universal and structural features of any body of knowledge. Further they can actually be used to organize knowledge in a number of non-equivalent perspectives, and adapted to handle soft ideas. While experts in specific disciplines make abundant use of mereological methods (though with restricted focus), such use is far less common in the literature on education research, and in the school curriculum. Therefore it is necessary to explain the the problems that its' adoption can address, and the ways in which it can be done.

The subject has a long history [Gruszczyński & Varzi, 2015; Camposampiero, 2019] that goes back to ancient times and almost every culture of the world has contributed to it – the latter aspect may be read as a license for universal adoption in school education. Formal approaches to mereology; however, started approximately at the end of the nineteenth century, while applications to STEM disciplines can be traced to the seventeenth century. The problems of interest have evolved with various kinds of gaps or breaks spread across philosophy, linguistics, the sciences and technology. Because of its breadth and varying focus over time it makes sense to split its development (and content to an extent) into mereology in ancient times, mereology during 17th-19th century, early 20th-21st century mereology, modern mereology for STEM, logic and philosophy.

Mereological predicates are best defined axiomatically because of possible variations, though context-dependent variants are additionally used. For example, the is-a-part-of predicate is transitive in only some theoretical approaches. It is usually reflexive, and antisymmetric [Seibt, 2017; Mani, 2019; Mani, 2012], and may satisfy some other properties relating to mereological sum and fusion. A few universal principles that may be valid in mereological contexts are atomicity (mereological atoms, that is entities with no proper parts, exist), atomistic compositionality (everything is ultimately composed of atoms), extensionality (no two composite wholes can have the same proper parts), unrestricted composition (any group of objects compose a whole), and mereological essentialism (if an object loses a part, it is no longer the same entity). Many generalizations and variations of these are known in the literature.

In a statement like "some critics admire only each other", the idea of quantification may be seen to range over pluralities of things that are not individual entities. Logically speaking, this is about the idea of plural quantification that range over pluralities that can be defined through mereological fusion operations . These are common in natural language (and essential for good grammar); however, are less commonly used in formal logic. The singular quantifiers of formal logic cannot express them adequately.

In this research, applications to key areas of STEM, related domains of discourse, and education are pointed out, and a proposal for veiled adoption in school curriculum as a common language that accommodates vagueness and uncertainty is made.

MEREOLOGY IN STEM

In this section, a few applications of mereology to different STEAM disciplines are mentioned. For applications of to the sciences, the edited volumes [Calosi & Graziani, 2014; Burkhardt Et al., 2017;] may be referred to.

Mereology in AIML

In AIML practices, *compositional representations* are used to reduce the complexity of models of complex synthetic environments. For example, objects such as cars, tables or humans recur in different scenes in distinct forms. However, a number of their features are respectively invariant across such scenes. Questions such as "does hair styling change the identity of a person?" are very relevant. In all this a wide variety of mereological relations such as is-a-part-of, is-connected-to, is-in-contact-with, is-a-functional-part-of and others are/can be used to generate the representations, with associated hierarchies. Some principles of object recognition at the practical level is, for example, described in [Felzenszwalb &Huttenlocher, 2005; Wang Et al., 2011; Zou Et al., 2017]. Approximate variants of the relations are additionally used by both humans and computers for the purpose. In [Mani, 2019], the relation is-an-approximate-part-of is studied in the context of its consequences. In [Zou, Et al., 2017] the authors additionally make use of approximate mereological relations; however, they do not explicitly formulate them in mereological terms. It is true that many practitioners do not have sufficient training in the related mereo-ontology, and this does affect the quality of models, or simulations they produce.

In the rough approaches to approximate reasoning in [Polanski, 2004; Polkowski, 2011; Mani, 2018; Mani, 2019], different types of is-a-part-of relations have a fundamental role in the models. Further, mereology is a fundamental part of the axiomatic approach to granularity, vagueness and approximation by the present author [Mani, 2018; Mani 2012].

The problem of reducing plurals or collectives through standard ontological relations is a fundamental problem of mereology. For example, cars, students, and forests are collectives with distinct ontological properties. Their components do not have the same distributive properties to start with. Often people in computer science and machine learning do not go into the issues in sufficient depth, and try to manage with shallow ontologies – and this is problematic. Apparently, the best practical solutions should be based on restricting the formation rules of collectives. In [Masolo, Et al., 2020], a formal solution to the problem is attempted.

Mathematics and Mereology

Mereology is heavily applied to different branches of higher mathematics and to the foundation of mathematics. Leśniewski's original program of founding mathematics on formal mereological principles as opposed to sets and classes (that involve mythologies of empty sets/classes) has led to variants and alternatives (see [Gruszczyński & Varzi, 2015; Urbaniak, 2013; Urbaniak, 2008; Aczel, 1988; Hamkins & Kikuchi, 2016]). Using constructive interpretations of *less-than* relations, intuitionistic mereological theories are proposed in [Maffezioli & Varzi, 2021] – this extends work on the constructive reals.

Point-free approaches to geometry and spatial mereology are well-known in the literature (for example, see [Gruszczyński & Pietruszczak, 2009; Vakarelov, 2007]), and the former are adaptable to replace those based on points at all levels. The latter is heavily used in computer vision, physics, and allied fields. In addition, applications to the mathematics of vagueness and approximate reasoning is a well-developed field [Mani, 2018; Mani, 2012; Polkowski, 2011].

Life Sciences and Cladistics

In biological contexts [Keet & Artale, 2018], parthood statements can be complicated both by ontological vagueness and by epistemic indeterminacy. For example, statements like "water is a part of the cell that it is in" or "intestinal flora constitute a part of a person" or "brain tumors are part of a person" are affirmed and negated by different ontological reasons. Body cavities are parts of a body because they defined by the body. Thus material objects can have apparently immaterial parts. Mereological essentialism breaks down often for living beings because identity is determined by a number of complex factors.

Cladistics [Lipscomb, 1998], is the best approach to the problem of classification and nomenclature of living and partly living organisms. Such entities with a common ancestor form a *clade*. Clades are further subdivided hierarchically on the basis of different criteria. Despite their widespread adoption, these are not taught in schools. The methodology has additionally been extended to astrophysics and historical linguistics.

APPLICATIONS TO EDUCATION RESEARCH

Applications to knowledge representation and evaluation in the context of student-centered learning are proposed in [Mani, 2020b]. Her proposal additionally seeks to model approximate and vague concepts used by students and teachers and provides a way of solving the problem of formalizability in mathematics (for example, see [Adler, 1999; Barwell, Et al., 2016]) in particular, because of the higher order approach used. Related classroom practices are reflected in [CCSS, 2010; Ding Et al., 2015]

It is well-known that the language used by students and teachers to express concepts, predicates, and predications in mathematics is frequently different from possible candidates of a standard language. They try to approximate these across semantic domains with partial success. Mereology combined with a language of approximations can potentially be used to build higher order formalizations of concepts that go beyond the restrictions envisaged in [Jayasree, Et al., 2022] because the very idea of the formal is much broader in the former through its' accommodation of vagueness and uncertainty. In the paper, the authors speak of coherent formalizability as a in these terms: "*By coherence, we mean that formalisation of disparate elements hangs together as a meaningful whole. The classroom discourse includes many parts pertaining to definitions, visualisations, representations, conjectures, exemplification, providing counterexamples, justification and refutation...*". It does rhyme with the proposal in [Mani, 2021], and approach to formalization in [Mani,2012;Mani 2018] and this research; however, they do not use mereology, or propose explicit formalization schema(s) of the *formalizable* that they adopt from [Adler, 1999].

The work on concept mappings in [Kharatmal & Nagarjuna, 2016] additionally makes uses of parthoods in an essential way. The latter has been adapted to classroom contexts in a limited way. A few other applications are discussed below.

The Signed Number Problem

Till at least the middle of the nineteenth century, western mathematicians were intimidated by negative numbers and their possible meanings . This was additionally due to their slow adoption of the decenary system and Indo-Arabic numerals. The difficulties faced by primary school students in understanding negative numbers (often known as the signed number problem [Makonye & Fakude, 2016; Kumar, Et al., 2017; Galbraith, 1974; Altiparmak & Ozdogan, 2010]) does have something in common with their problems. In school mathematics, mereological ideas of is-bigger-*than*, is-*smaller-than, is-composed-of, is- connected-to* and others are encountered by students. These are not always defined in clear terms, and may be part of word problems. The solution proposed in [Kumar, Et al., 2017] implicitly refers to ideas of is-bigger-*than*, and is-*smaller-than; however,* fails to argue about possible size.

It is argued by the present author in [Mani, 2021] that "the meanings of negative numbers depend on culture and perspective, and it makes sense to construct amenable ontological explanations that are in tune with mathematically accepted meanings and use of such numbers". In the paper, a new way of teaching negative numbers that exploits mereological understandings of emptiness is proposed. It is first pointed that from the perspective of pedagogic content knowledge [Ball Et al., 2008], approximate models of real numbers are correctly taught in primary schools, and the symbols + and – are ambiguously used as binary and unary operations.

In the same paper, it is argued that the problem of signs is due to inconsistencies in the ascription of ontologies to the real numbers. Specifically the concept of zero is read in a way compatible with the real number field alone. Universal concepts of emptiness are not compatible with most mereologies as emptiness is typed. This results in a distinction between the *thing being perceived* and *the result of inference through a logical process.* In simpler terms, the question to be asked is "How is something empty?".

In the proposed approach, every emptiness needs to characterized in a way that is compatible with the context. Further, it is argued that there is big difference between the numbers used for counting and the property of the thing being counted. The proposal based on the former argument is quoted below:

> Most importantly, it suffices to introduce a large number of common possible types of emptiness to enable concept development. Thus what is traditionally taught as an empty glass can be a -50 marbles empty glass if the glass in question can be filled with 50 marbles and it is that the proposed activity concerns filling glasses with marbles. At the same time, the glass is not -1 cabbage empty because it cannot fit in a cabbage, though it is -1 drink empty. The idea of zero in these contexts would then be about possible give and take operations in the absence of such in reality. It may be noted that in ancient Chinese

mathematics, a debt would be the same as possessing a negative sum.

Geogebra and Simulation Based Learning

Geogebra is a versatile free software for learning a wide variety of mathematics including calculus through simulations and dynamic models. Aspects of the structure of concepts in typical online or offline classroom settings is explored here to illustrate the use of mereology in a dynamic setting. The reader is referred to [Bu & Schoen, 2011; Venema, 2013; Machromah, Purnomo, & Sari, 2019] for varied uses of the software.

While transformational geometry is almost natural in Geogebra, an exercise from [Venema, 2013] illustrates the dynamic aspect of doing geometry:

> 3.2.2. Make a new sketch that illustrates the Euler line theorem. First construct a triangle and then use the tools from 3.1 to create the three triangle centers. Hide any intermediate objects so that only the triangle itself and the three triangle centers are visible. Construct a line through two of the points and observe that it also passes through the third. Add hide-show check boxes for the triangle, the three centers, and the Euler line. Add text boxes and check boxes for the definitions of the three triangle centers as well as the statement of the Euler line theorem. Make sure that you have made good use of color and explanatory text so that your sketch is user friendly.

This flexibility naturally permits the creation of unexpected concepts that differ in value to the point that evaluation becomes difficult and error-prone especially because of limited time and the absence of sufficiently skilled teachers (which is often the case in a number of settings). Therefore there is a need to help teachers and with additional soft tools.

A student, for example, can learn about aspects of Pythagoras theorem, the connection between circles drawn with the hypotenuse of a right-angled triangle, and circum-circles of such triangles without ever knowing much about the proof(s) proper. This illustrates the point that learning from simulations and a finite set of perceivable models has its limitations. It is additionally prone to paradoxes, and visual proofs may actually be wrong. While a formal approach can help in specifying directions of concept learning through software-based recommendations, the situation would be far better if the student can possibly describe their operations in a spatial mereological language. The language can provide the necessary affordances [Heft, 1989; Chemero, 2003] for proper representation, and enable reasoning. This aspect is masked in studies such as [Karnam Et al., 2020] that stress the affordance aspect provided by soft tools for geometric reasoning (in an algebraic perspective). Note that these claims do not require entirely valid theories of embodied cognition for their validity [Goldinger Et al., 2016].

TAKING MEREOLOGY TO SCHOOL

In the previous sections, it has been explained that mereological methods and concepts are essential for a wide range of theoretical and practical applications in all subjects, and that it can *serve as a universal language for all subjects at all levels*. While dedicated chapters on parts and wholes can be taught, it is necessary to introduce more of the reasoning machinery in different subjects. In a chapter dedicated to parts and wholes, it is not easy to cover such a wide range of applications because it would be too strenuous on teachers and students. Further, mereological predicates are too many in number, and interdefinability does not happen always (*apartness* for example, requires plenty of context to be expressed in terms of *is-a-part-of*).

For these reasons, the best strategy would be to systematically revise, upgrade and add key topics to elementary mathematics, ICT-enabled mathematics, physical sciences, computer programming, life sciences and language. The last because, good grammar is a mereological discipline. As already pointed out that lessons on fractions invariably concern measurable parts and wholes,however it is not stressed that not everything is measurable – this has a detrimental effect on students' attitudes towards vagueness, uncertainty, and scientific thinking. While the introduction of chapters on cladistics in biology is bound to involve plenty of effort at all levels, the process is unlikely to be easy in the other areas, especially because of the teacher training programs that would need to be undertaken. Some possible thrust areas are mentioned below.

Areas where software and simulations are used should be thrust areas to ease the process of adoption, because they can serve as avenues of exploration, testing, and practice of the concepts learnt. In Geogebra and similar software, a proper description of the visual proofs that happen or those hidden in programs are possible only through a proper language --this is something that students do not really have access to. A knowledge of mereological methods can provide the necessary affordances for reasoning with action.

In primary school mathematics, apart from the novel approach to teaching the signed number problem, the language of arithmetic needs improvement especially in relation to the differences between unary (1-place) and binary (2-place) operations such as – (minus) and – (minus) respectively. Parts and wholes feature in the study of fractions and multiplicative thinking,however the assumption of measurability or countability is too strong, and – for example, this is the case in [Lamon, 2020]. This excludes many types of functional parts from the discourse and generates tunnel vision in learners and teachers. A reflection on the nature of mereo-ontology [Vieu, L. & Aurnague, 2007; Winston Et al., 1984] in the contexts of the book demonstrates more. Therefore this problem needs to be addressed at multiple levels.

In future work, the directions mentioned will be explored and described in more detail.

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THE POSSIBLE MISSING INGREDIENTS IN ENGINEERING HIGHER EDUCATION –MASTERING SELF, AGENCY TO SHIFT DISEMPOWERING NORMS AND SOCIALIZATION AND MASTERING TECHNICAL SKILLS

Arun Arulselvam[1, b, !], Narmadha Anandavelu[1, a, @], Santhosh Kathiresan[1, b, #], Sivaraman Ramamoorthy[1, b, $], Sri Bhavani Arul[1, a, %], Sanjeev Ranganathan[1, b, ^]

[1] C3STREAM Land, SAIIER (Sri Aurobindo Institute of International Educational Research), Auroville

[a] she/her/hers, [b] he/him/his

! arunarul677@gmail.com, @ narmadha29101997@gmail.com, #sandykias@gmail.com, $ aurosivaraman@gmail.com, % sribhavani1998@gmail.com, ^sanjeev.ranganathan@gmail.com

Engineering higher education in India, especially rural India, does little to help youth learn about the universal values they stand for or develop their inner capacity, or develop agency to address disempowering socializations, it does not even prepare youth with practical industry ready skills. What possible missing ingredients when put in place would prepare youth for a effective and meaningful life for themselves and others? This paper is an autoethnography of five youth who are completing a one-year residential program called "Being and Becoming a Shifu (Master)". We present how the program added these missing components in helping us connect with universal values, develop system thinking and five minds of the future, confidence in skills, being independent and interdependent and self-assessment.

RESEARCH QUESTIONS

The one year *Becoming and Being a Shifu (Master)* (BnBShifu) program helped us youth understand what we care about, increased self-awareness, self-regulation, responsibility, and develop confidence technical skills of VLSI (Very Large Scale Integration) layout and programming. It helped us notice our own socialization, develop system thinking. This helped develop the five minds of the future - disciplined mind, ethical mind, respectful mind, synthesizing mind and creative mind. We reflect on 'how this happened', or perhaps, how this could happen in Higher Education (HE) with practices at BnBShifu and its impact on us:

1) How did the program encourage youth to connect to their universal values (universal values apply for everyone, everywhere such as dignity, equity, courage)?

2) How did the program support develop system thinking, noticing patterns and five minds of the future?

3) How did the program build confidence in skills and in competence to move from being dependent to independent to interdependent?

4) How did the program provide timely feedback and build the ability of self-assessment?

We refer to *universal values* as those that can be embodied by everyone, everywhere irrespective of their caste, culture, gender, age, etc such as dignity, equity, courage. These form the basis of sustainable and equitable change for a thriving people and planet (Monica, 2017).

As Monica states:

> When we source universal values, and express them through strategic action, multitudes of initiatives come alive, and a vast array of ideas find expression based on our aspirations, interests, and talents. Our independence is wholesome through our interdependence.

We distinguish these from the common uses of the word values in different contexts such as - something important; or a socialized culture (of a specific group, caste, or religion e.g. how women/men should dress); or in business as money added at a stage in a value chain; or as operating principles (e.g. excellence in academia, privacy in online transactions) which varies with context.

HIGHER EDUCATION IN INDIA: CHALLENGES & OPPORTUNITIES

The quality of the HE institutions and colleges in India is not on par with other countries like China, Singapore (Singh, 2011). Singh states that some of the institutions are run as a profitable business where the rural and semi urban pupils are trapped. In our county 68 percent of the country's universities and 90 percent of colleges are "Middle or poor quality". He recommends institutional sharing between high quality institutions and these to take them to the next level. (Sheikh, 2017) suggests an alternative paradigm of new-age online learning tools to address various challenges of Indian higher education and to bring equity. Contemporary research (Manya, 2020) indicates that the Indian Education system is concentrated more on the marks rather than giving importance to the skill that has been built. Specifically, the unemployment in Engineering graduates is due to a lack of skill and competence (Tilak, 2021). Tilak shares that technology is transforming the labour market across the world 80 percent of Indian engineers are not fit for any of these jobs. India needs to interlink academia and industry.

To improve learning outcomes in HE (Harackiewicz & Priniski, 2017) suggests targeted interventions in how students value their tasks, how they engage with their academic work and their communication with their professors. Across domains students who framed their academic challenges and could self-reflect were more motivated and had better outcomes. Other solutions are linked to the need for feedback in improving the learning experience for the students in HE (Bashir, Kabir, & Rahman, 2016). That providing quality information to students about their learning and feedback to the students develops the ability of students in self-assessment.

Further there is a question of what HE should inculcate. (Ronald, 1990) argues the hidden understanding of HE beyond economics is the need to develop physiological and sociological perspective in students. Ronald highlights certain points that can be included in HE like self-reflection, open learning, group activities, interdisciplinary learning that can lead to developing these aspects.

We feel that the five minds of the future (Gardner, 2005) synthesize what is needed by youth - the disciplined mind (understanding, application and memory) for skills, the respectful mind (dignity for all), the ethical mind (human unity) caring for people and planet, the synthesizing mind (ability to notice patterns) and shift unhealthy socialization and creative mind for new solutions from care as distinguished from innovation which is only a function of the mind.

In this paper, we will look at how the BnBShifu program which offered no marks or certification developed our skill, competence and inner capacity. It started with connecting us to our potential or inner values and developing technical skills needed in the industry embracing the solutions suggested in literature including feedback from mentors, self-assessment, setting targets, peer learning, using rich online resources.

RESEARCH METHODOLOGY

The primary research methodology is autoethnography based on reflections of five youth (represented as ShifuX: Shifu1, Shifu2, etc) who are completing the BnBShifu program. We feel that a methodology based on reflection is appropriate as we are addressing the lack of the reflection in youth and in our education system. We hope multiple reflections mitigate the weakness of autoethnography of not to being general enough. The gaps in HE described in literature is our lived experience as engineering graduates in rural India. We hope what was useful for us in BnBShifu will be useful for further interventions at scale.

Based on general reflections on the program we came up with questions that we felt might give a framework for us to synthesize our experience making it relevant for a broader audience. We then recorded our reflections for these questions. Given the limited length of the paper we have been selective in sharing insights and may have cut them short with '...' in the hope to bring a new point. We have also dropped a question regarding how the program helped us develop healthy living which we felt was important to share with youth, but we realize many aspects were possible due to the residential nature of the course and may not be scalable. We will make all responses including those of a couple of new joiners (3 months) of the BnBShifu program available online after the review process (Arulselvam, Anandavelu, et.al, 2022).

BACKGROUND OF PARTICIPANTS OF BNBSHIFU PROGRAM

Sharing our background before we joined the BnBShifu program may aid understanding our reflections. We all studied engineering in colleges in villages around tier-II/III cities as shown in Table 1.

Who	Age	Course	M/F	College Location	Work-ex
Shifu1	23	B.Tech. EEE	M	Ariyur, Puducherry	0
Shifu2	23	B.Tech. ECE	F	Serumavilangai, Karaikal	8 months
Shifu3	24	B.Tech. ECE	F	Serumavilangai, Karaikal	0
Shifu4	24	B.E. EEE	M	Chellankuppam, Cuddalore	1 year
Shifu5	24	B.E. ECE	M	Mailam, Villupuram	9 months

Table 1: Background of participants of the BnBShifu program (and authors of this paper).

REFLECTIONS TO DESCRIBE THE BNBSHIFU PROGRAM

Shifu1: In my college they focused only on marks and I memorized to clear all papers and not get arrears. I could tell the memorized definitions, but had no in depth to explain further. Sometimes I even forgot the definitions as I had not understood them. Even in practical exams I memorized the circuit connection by using a manual. When asked, the lab staff did not offer us an explanation of how things worked as they felt it was not needed to pass the examination.

Shifu2: I thought scoring high marks will help me to get a job in the tech industry. After college, I got a job as a data entry operator. There was no progress in my learning except achieving targets. There I didn't get time to take care of my health or engage in any other S

Shifu4: When I first heard about the program, I thought that it will be like other usual courses of training in programming, but it was totally different from my imagination.

The application form itself was completely different from anything I had ever seen. It asked about personal *information* (e.g. biodata), personal *knowledge* (e.g. if I prefer to work early in the mornings or late at night) and personal *wisdom* about self-analysis, self-awareness, self-regulation, responsibility. Especially the wisdom section where they asked for universal value, cultural shift, responsibility, and healthy habits was a different experience for me and made me think.

We started the day with Surya Namaskar, running and Anna Paana meditation. We then had team meetings often with RTL (Radical transformation leadership) training sessions (Monica, 2017) and then we concentrated on learning skills and then I practiced to make myself perfect. We interacted with each other and with our mentors to learn and also had sports or gym in the evening, at times we watched TED talk and reflected on it and the day was completed with book reading and daily reflection.

The RTL program helped me to find what I stand for and be one with my universal value; the program offers tools, templates and distinctions that connect real-life experiences and help me see problems from my universal values and come up with solutions that are in line with them and the shift I want to see in the world. It helped me address my bias and socialized fears and gave me a path to overcome them…

Shifu1: In this program I learned I stand for kindness and equity for myself and others. I committed to spending a year in the Shifu program as an input from my side. The output of the program was that I learned VLSI layout, programming in Scratch¸ Python & SKILL, Radical Transformation Leadership (RTL), Spoken English, Maths class, Book reading session, and Vipassana (VRI, 2010)... I learned to meditate and notice myself. I also changed my food pattern to a healthier diet and avoid snacking… I joined the program for technical knowledge, but here, I also learned useful life skills and RTL tools. The program also gave me time and space to think about the purpose of my life…to notice that only earning is not going to fulfill my life so I learned to serve and help others. I started teaching children (in my last semester) what I know, while teaching, I noticed that I'm also learning from them.

Shifu3: .Here the first one or two weeks it felt that we were doing so many things like learning technical skills, sport, meditation, and following ground rules...But, as I settled in, I learned time management and created time for everything to have an enriching day, each day…We also had access to STEM land a space with games and puzzles created for children where I went to learn and refresh myself. Every week we visited some places in Auroville and met new people who they shared how they are serving the community and what they care about and I was inspired to be courageous and independent like them. Once a week we also presented what we learned to others. Everyone in the program had taken up accountability like managing the kitchen, finance, maintenance, and so on this made me more responsible and accountable.

An important point that came up in all reflections was developing good habits of being disciplined about eating times, and being healthy mentally and physically.

REFLECTIONS ON THE RESEARCH QUESTIONS

How did the program encourage youth to connect to their universal values*?

Shifu1: All of us have universal values within us, but we do not notice them or not act from them. This program had RTL which helped me think about my universal values I really care about for myself and others. Whenever I share an insight, I start by sharing my universal values.

I stand for equity and kindness for myself and for others. When I keep on telling my universal values they became automatic I acted though equity and kindness. The words allow me to connect to what I deeply care about, but I'm not stuck to the words and understand their essence is to make me better. I believe RTL tools, templates and distinctions can also support youth to connect to their universal values.

Shifu2: I learned who I am being when I am at my best i.e. the universal values I hold within. I noticed that what I admire in others are qualities I want to develop within me. After discovering my universal values, I started to work from them. It made me think differently of how I can handle situations. I started to notice situations when I was not in my universal values and reflect and shift my mindset. The impact and outcome of practicing some RTL tools is it made me notice my own bias towards genderism and my own background conversations.

Shifu3: This program helps me become more self-aware and I discovered the inner values I stand for equality and happiness, through RTL. I used tools in RTL to overcome my fear and work courageously. It also made me aware of what I am doing in every situation and I learnt how to process experiences and learn from them. I started to design my projects using CFSR. I can breakdown the problem and what are the actions I can do differently to progress. I learned to be responsible.

Shifu4: .It starts with the searching what a person deeply cares about and makes him/her understand their stand... It helped me change my mentality from caring only for 'me, myself and I' to caring for 'myself and others'. In addition, the Shifu program supported my problem-solving ability even technically and gave me confidence in facing the problems instead of getting into fears...We had ten days of Vipassana meditation which helped me to come out of my cravings and accept the reality to move forward. It helped to develop a concentrated mind.

Shifu5: The complete awareness of my values and for what I stand for came after attending RTL workshop…Here the values have important essence of connection for goodwill, strength and supportiveness for everyone universally.

How did the program support develop system thinking, noticing patterns and five minds of the future?

Shifu5:

The Disciplined mind: The program gave me the time stay with topic till I understood, applied and remembered it. I found this way of learning to be an investment for my life and it stood as a north star for my life as a programmer and being human.

The Respectful mind: Here the learning was without hierarchy. Learning from each other and supporting others to learn emphasized respect for everyone...

The Ethical mind: Vipassana meditation helped me be moral and dignified and supported put the RTL tools in practice not only being moral, ethical, but also integral (whole)...

The Synthesizing mind: I used to memorize information, but synthesising helped me retain and look for patterns and use learning in other contexts. This included learning programming and problem solving in code-wars, reflections at the end of the day, processing a TED talk or a workshop.

The Creative mind: There are no ready-made answers to important challenges and I learned to be creative and adapt. There can be one good answer, but I learned to look for alternative possibilities that emphasis goodwill…

Shifu2: After I learned the basics, I completed a task in that domain. After completing several tasks, I worked to synthesize the new ideas that I learned. Then I connected new learning with what I already knew. This helped me to learn new domains easily... When I heard presentations from others summarizing what they had learned and I needed to present my own learning I learned to synthesize.

Shifu3: Initially, I wondered why with VLSI specialization I was learning programming, but as we went along I realized that I had developed my logical thinking, problem solving and automation that I applied to my specialization. I applied logical thinking in the electronics lab and the process of taking small tasks and going in depth and completing it helped me learn something new that I can use to work efficiently in the next task.

How did the program build confidence in skills and in competence to move from being dependent to independent to interdependent?

Shifu1: When I was new to this program, we experienced doing experiments in an electronics lab… I never had this kind of exposure in my college to do individual work…

Shifu2: Initially, I was dependent on my mentor to learn new techniques and skills in VLSI layout, then I was given tasks. As I completed tasks, I felt more confident to work independently. I noticed it took more time to complete tasks alone as compared to when I had peers who I could talk to. Sharing of new learning and discussing with peers made me feel interdependent and more efficient. This built my confidence and faith in working as a team.

Shifu5: Before joining BnBShifu I thought I'm not the type to learn programming. In the program a personal mentor guided me based on my capability. I was introduced to learning at my own pace online using the Coursera platform that had many courses that were project based. Every time I made a project, I felt more confident. When I got stuck, I got the support of my mentor who would ask me questions rather than just give answers. After that I was introduced to code-wars a website for challenges in coding at various levels. Here, I needed to pick my challenge and I started to understand where my level was and could see how I was able to take up challenges at higher levels as I got better in programming. I became independent and could assess what I was capable of. Relating what I do with my values and in resonance with the five minds of the future gave me interdependence.

How did the program built the ability of self-assessment as well as provide timely feedback?

Shifu1: In this program we had an opportunity to record our insights - reflections about what I learned and about how I feel here in our daily reflections. Our mentors read and interacted with us and this helped to clear our doubts in the same day itself…

Shifu2: Getting the input and feedback from my mentors, helped me to level up my state of progress. In technical skills, mentors supported me and gave feedback that helped me notice my gaps. In time, I started noticing my own gaps and this self-assessment had a major role in my progress and learning e.g. noticing how much time I took, what ideas from a previous tasks I could have used to complete this task.

Shifu3: In college I just got marks and neither got feedback from my teachers nor did I find where I made mistakes to correct myself. But in the BnBShifu program mentors supported me by giving feedback for growth (increase, decrease, retain) to improve myself helping me identify where I was and progress swiftly.

Shifu5: I feel self-assessment of looking at patterns of how I did things and how I can make it better is the best way of assessment and helps get many creative answers. This gave me courage to neither give up if I don't get the answer nor stop with a single answer...

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CONCLUSIONS

We the youth describe the missing ingredients of our education system were experienced in BnBShifu program. Here we built our leadership skills through RTL training that helped us learn what universal values we deeply cared about and want to manifest in the world building our respectful, ethical and creative mind. We developed our disciplined mind with the support of challenge-based online courses like Coursera and platforms like code-wars and practiced self-learning, peer learning, presentations, feedback and got guidance from mentors (practitioners). We developed our synthesizing mind with daily reflections, using RTL tools to process experiences and presenting what we learned technically to peers. We had access to practitioner mentors who asked us questions rather than give answers and gave feedback that helped us notice gaps and build self-assessment. As we built projects we moved from dependence, to independence to interdependence in creating a learning community with peers. There were no specific teachers, professors, no marks or certificates and yet we learned an found meaningful employment. We work in the areas of VLSI layout, software design and design automation while putting aside time to support others learn what we know as others who invested in us through the BnBShifu program. The third area design automation is a combination of the first two and was created as the program progressed.

We feel responsible to question status quo in the norms of our education system and to showcase what needs to be added to make the education system whole. We hope these ideas from this program will be scaled to benefit rural youth like us in India.

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UNDERSTANDING THE PROCESS OF MEMETIC REASONING IN GRADUATE STUDENTS DURING COVID-19 - *IF YOU KNOW WHAT WE MEME!*

Anveshna Srivastava[*#] & Chandan Dasgupta[*!]

*Educational Technology, IIT Bombay, Mumbai, India

[#]anveshna.sriv@gmail.com*, [!]cdasgupta@iitb.ac.in

Memes are the packets of information that we acquire by interacting with other people. In a narrow sense, we connect meme with its popular form on social media, where we happily consume, create and transmit it for its humour and/or sarcasm. Given the current pandemic state, when the teaching-learning process has been hit hard with unpredictability, it is apt that novel steps are taken to restore some sense of normalcy and ease students' stress and anxiety. It is both this motivation and the cognisance about the role of memes on digital platforms that a mid-semester exam for a course on human-computer interaction (HCI) was modified to encourage graduate students to give way to their memetic expressions. As part of the exam, 15 graduate students were asked to design five different memes based on their readings and discussions in the HCI course. This activity was followed by a survey to elicit students' understanding about the designing process and to probe their memetic reasoning. In this study, we identify meme-cases to reveal students' perceptions and also share the findings from the survey which suggests that majority of the students -a) enjoyed creating memes for their exam, b) referred to more than four different resources for creating their memes, c) referred to most of the content for the course, and d) did not actively seek feedback for improving their memes. Implications are drawn from the study to use technology and social media to design novel methods to engage students with their learning process.

INTRODUCTION

Memes are identified as units of culture which, like genes, are passed from one generation to the other (Dawkins, 1976, p. 249). We get these 'packets of information' from our ambient culture when we interact with other people and, by plain imitation, we copy these memes in our minds but since copying is imperfect, we may add or remove some aspect of the information (Blackmore, Dugatkin, Boyd, Richerson & Plotkin, 2000). And, further, when we share this transformed information with other people, we participate in propagating this meme. It is easier to see how only sturdy information can withstand the pressure of endless copying and transmission. Memes like music, religion etc. stand the pressure of time and get copied generation after generation.

In this age of digital platforms, the concept of meme has a more concrete existence. A meme is considered to be a piece of culture, typified by humor, wit and/or sarcasm that gains influence through online transmission (Davison, 2012). Memes or pieces of information usually take the form of images, presented as pictures, GIFs or animations, taken from other media (popularly from movies, television or print) and connected to everyday life and often overlayed with specific phrases or quotes (Brown, 2020). Since the current generation of learners is attributed with higher usage of digital devices, digital media, and social media in their daily lives (Taylor & Keeter, 2010), it is natural for them to be an avid consumer and/or creator of internet memes.

Coming to our social lives, the outbreak of Covid-19 and the subsequent lockdown of schools and offices have led to higher level of stress and anxiety with adverse physical and mental consequences (Flesia, Monaro, Mazza, Fietta, Colicino, Segatto, & Roma, 2020). Further, as the institutions of learning have been forced to move to online platforms, this tectonic shift in modality of learning compounded by other factors has led to higher levels of stress and anxiety in school students too (Ningsih, Yandri, Sasferi, & Juliawati, 2020). It is in these situations that the role of technology becomes imminent and the education community, worldwide, is working to make online forms of learning meet the challenges of distance, scale and personalized teaching and learning (Basilaia, Degebuadze, Kantaria, & Chokhonelidze, 2020).

It is in these circumstances that we share an alternative method for helping students to engage with their learning process. Construction of memes has been largely used as a subject for digital literacy and culture (Shifman, 2013). However, quite recently, memes have also been explored as innovative methods to engage with students' learning (Brown, 2020; Underwood, & Kararo, 2020). Our work makes a stride in this direction and uses meme-construction in an exam, based on the readings and discussions in the course, as a way to help students express their thinking and understanding in a more unstructured manner. This work assumes that the usual structured nature of exams gives a lot of weightage to the process of memorization and recall, which in turn leads to stress and anxiety in students (Spangler, Pekrun, Kramer, & Hofman, 2002).

Furthermore, since we unintentionally create and transmit memes all the time, it becomes difficult to reflect and think about the form and quality of all these memes. However, when we are forced to deliberately design a meme, the process of meme-construction promotes our ability to think critically about the pieces of information that we are bringing together for the world to see (Wells, 2018). Also, since memes have a larger visual field with limited text, it pushes students to think hard about which concept needs to be focused upon in the image and what text should accompany it for bringing coherence in the narrative. This gives ample opportunity to the students to voice their expression and also be creative, while being able to represent the conceptual point.

METHODS

Sample

15 students (6 M; 9 F; Mean Age - 27; SD - 5.02) participated in the study. All students had done their bachelors and were either pursuing masters or doctoral degrees, and were enrolled in common courses. This study was conducted as part of their HCI (Human-Computer Interaction) course, offered by the Educational Technology department of the concerned institute.

Task and instructions

As part of their online conducted mid-semester exams, students were asked to create five memes, individually, based on the readings and discussions in their HCI class, which had been conducted in an online format. Further, they were given specific guidelines to create original, unique memes with clear ideas, without focusing on the teaching process, instructor/TA and the HCI field in general and they were also asked to not be disrespectful to anyone, to not use any foul language or adult media in their memes. This question carried a maximum score of 10.

Students were also asked to post their memes on a slack channel of the department, where other members could engage with the memes and post their reactions. Students were themselves barred from reacting to these memes. Since each student had to create five memes, they had the opportunity to share a meme and then gauge its overall quality based on the feedback received from the general audience. This feedback could then be used to improve the next set of memes. To let the students be more involved with the task, a bonus score of 5 was decided for the meme with maximum number of reactions. The rubric for evaluating the memes was also shared with the students before the conduct of the activity. It contained the parameters of ‘execution’, ‘cohesion between ideas’, ‘creativity’, and ‘relevance to the course readings and discussions.

Data sources

Student generated memes and the post-exam survey responses form the major sources of data.

ANALYSIS

In this study, we do not share the results of evaluating students’ memes for assessing their conceptual understanding. Rather, we analyze memes and present specific cases of students’ memetic expression to identify gaps in the teaching-learning process, to recognize students’ emotions, to observe critical thinking and to draw inferences about students’ ability to understand and represent one’s own and a differing perspective. Later, we present our analysis of students’ responses to the survey questions.

Meme cases based on memes generated during the HCI mid-semester exam

Using memes to identify gaps in teaching-learning process: Given that learners come to the class with some prior understanding and that they carry different sets of memes (Yoon, 2008), it adds to the complexity of the teaching-learning process. This is because multiple copying of memes/information can lead to mental chaos and it may become difficult for students to meaningfully connect the central concept being discussed with other relevant concepts. For instance, the meme in Fig. 1 demonstrates this complexity and the student uses the analogy of dirty/used utensils to represent his/her scattering of thought after the ‘meal’, which can be mapped on to the classroom discussion. The accompanying text makes the analogy explicit.

Fig. 1: Meme demonstrating the scattering of thought after a classroom discussion

Using memes to recognize students’ emotions: Students’ emotional state influences their academic performance and, hence, it is useful for instructors to recognize and take cognizance of students’ emotions. In Fig. 2, a student demonstrates his/her aversion to regular mode of exams, which are usually a source of stress and anxiety because they encourage rote memorization and expect students to recall concepts. The student also uses the contrasting emotional state representing content and happiness for the case of an ‘open book’ exam, where students do not feel pressured, as they can refer to the book for answering questions.

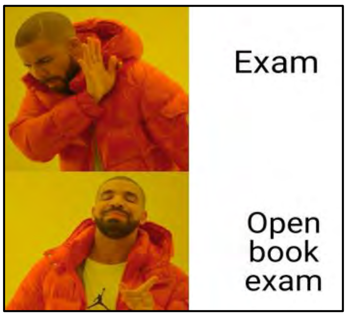

Fig. 2. Meme demonstrating student's aversion for usual exam and liking for 'open book' exam

Using memes to assess students' critical thinking ability: One of the major goals of education is to promote students' critical thinking ability. Critical thinking is reflective and reasonable thinking focused on deciding what to believe or do (Ennis, 1985). In Fig. 3, a student uses a series of questions accompanied with two images that represent her skepticism. The student reflects on the material cycle of life and critically thinks through the process and, further, also maps it on to the reasoning aspects of the 'fishbone' diagrams, a concept covered in the course.

Fig. 3. Meme demonstrating student's scepticism about the material cycle of life

Using memes to assess students' perspective taking ability: Perspective taking is the ability to move away from one's point of view and consider placing oneself in someone else's position mentally. This is done to understand another person's perceptual or conceptual position. For instance, in Fig. 4, a student demonstrates his/her perspective-taking ability by representing how a good designer faces contrasting issues that make it hard for him/her to stay put and find the right balance to make things work. The meme represents an animal, symbolic expression for a good designer, that struggles to balance and stand erect when it is standing on four different cans.

Fig. 4 Meme demonstrating the contrasting issues faced by a 'good' designer

Survey responses

A survey was conducted to elicit students' thoughts about the meme construction activity. Below we describe the patterns that were observed from the students' responses.

Majority of the students loved the exam activity of meme construction: We observed that exams which are typically stressful for students in the learning process turned into an activity which students were looking forward to doing. They also expressed happiness at being able to de-stress in the middle of the exam week while actually giving the exam for this course. Students were responding to the following question-Q. What do you think about the use of memes in midsem?

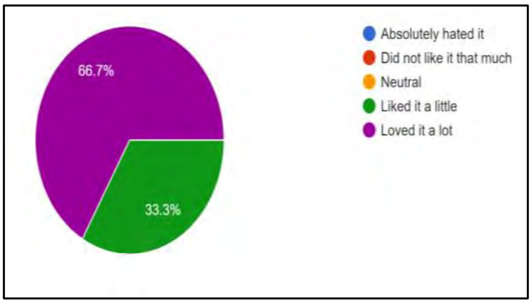

Fig. 5. Students loved meme construction activity

Majority of the students referred to more than 4 resources for constructing the memes: The meme-building exercise forced students to refer to different resources, most of the times. The reason could be related to the search of relevant template or relevant text or relevant mapping of the content. Students were responding to the following question - Q. How many resources did you refer to before creating your own memes?

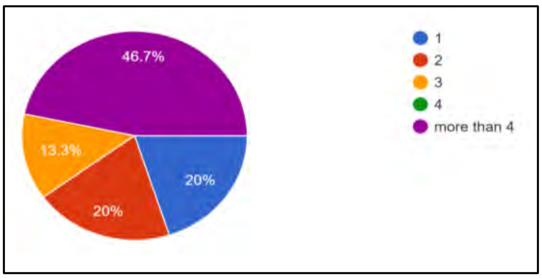

Fig. 6. Majority of the students used multiple resources for meme construction

Majority of the students referred to most of the course content for constructing the memes: Majority of the memes constructed reflected student's ability to critically think about the HCI concepts in an interconnected manner and synthesize them while creating the memes. Students also reported that they had to find appropriate images that conveyed the meaning of the concept driven text. This was an iterative process that may have helped them engage in critical thinking. Students were responding to the following question - Q. How much course material did you refer to while creating memes?

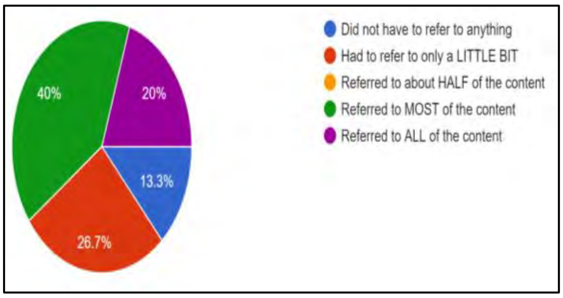

Fig. 7. Majority of the students referred to most of the course content for meme construction

Majority of the students did not seek feedback from others to improve their memes: Even though majority of the students did not actively seek feedback on their memes, there is a possibility that reactions to other memes might have implicitly seeped into the design of their latter memes. Students were responding to the following question - Q. How much *feedback* did you seek on the memes created by you to improve them (from classmates or others)?

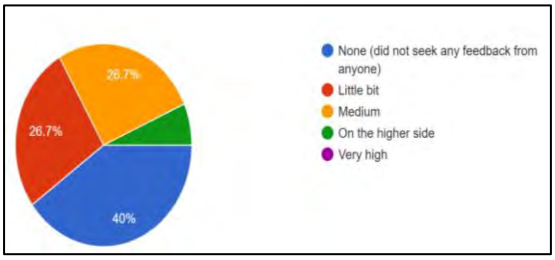

Fig. 8. Feedback had a limited role in students improving their memes

SUMMARY

The study reports on an alternative method of meme-construction to help students engage with their learning process. As part of their mid-semester exams, students were asked to construct memes and post-activity, they were asked to reflect on this process via a survey. We analyzed the memes to look for different ways in which one can connect with both students' perceptual as well as conceptual positions. We found that memes can act as windows into students' emotions, their critical thinking and perspective-taking abilities, along with imparting their insights about the teaching-learning gap. We also found that students enjoyed the meme-making activity for their exams and it likely reduced their exam related stress and anxiety. They also referred to multiple resources and covered most of the course's content for making their memes. However, contrary to our expectation, the majority of the students did not seek feedback from the audience to improve their memes.

Implications and Limitations

In this era of Covid-19, when teaching-learning has shifted to digital platforms, both instructors and students are missing out on the warmth and comfort of face-to-face interactions. As a consequence, there are issues of being isolated from the community. During the normal offline classes, it was easier for instructors to gauge students' emotions and perceptions and conceptual understanding. Use of gestures, facial expressions and body positioning were all used as cues to dynamically give and receive feedback but online classes have created a huge gap in this regard. However, through this study, we report on how using online technological resources, we can help students to ease their stress and uncover their implicit insights and perceptions about the teaching-learning process. It is in this latter sense that memes are powerful as they give expression to an individual's voice without making them actually speak.

There are several limitations to this method of engaging with students' learning. Foremost is the inability to generalize the meme case findings across different sets of learners. It is not necessary that memes will reveal perceptual insights for all the learners. However, it shows one way in which instructors can connect with students and get some insight about their perception. This also creates a potential space where reaching out becomes feasible. The other major issue is about the inability to assess students' understanding about multiple concepts taught during a course. This limitation cannot be overcome within the constraints of the meme-building task. However, on the positive side, here students are free to choose a concept of their interest and work with it and when they construct a meme, they get involved with all aspects of the concept in focus. This may help them construct a sound understanding about the particular concept.

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USE OF ANALOGIES FOR CLASS 6 STUDENTS TO CLASSIFY PLANTS: VERBAL ANALOGIES VERSUS ACTIVITY-BASED ANALOGIES.

Pratistha Agarwal[1!] and Kruthika BS[1#]

[1]Prayoga Institute of Education Research, Karnataka, India

[!]pratistha.ag@prayoga.org.in, [#]kruthikabs@prayoga.org.in

This study revolves around the ways of teaching science for young learners, focusing on analogies. Using analogies keeps the learners involved at all times and helps them connect their real-life experiences to the subject. At the same time, it is very important to follow a method that suits the classroom/student set. In this study, the student sample considered belongs to a rural background and face a learning gap due to the epidemic situation. The authors have compared the subsequent use of verbal analogies with that of hands-on activities. This was done while teaching the module on "Plants" and students were asked to classify land plants based on criteria that they find suitable. It was found that while using the verbal analogies, students were able to comprehend but could not make the connect. On the other hand, after performing hands-on activities, students successfully came up with expected answers for the posed question. The authors also talk about how this scenario is a typical example of teacher reflection in the classroom and how they could benefit from it.

INTRODUCTION

Science is a way of life. It is an integral part of every living being. In order to appreciate the importance of science in our daily life, it is very crucial to engrave scientific temper and attitude in every child at an early age (Lindholm, 2018). In this regard, it is very important to take utmost care of "what children learn and how they learn", particularly in science. To keep a check on this, the mode of instruction used plays an important role. Science learning should never be a mere transfer of information from the teacher to the students. Most education researchers agree that science learning is better when the learner is allowed to experience science while learning it (Morris & Morris, 2019).

In order to achieve maximum learning in a science classroom, there are various teaching methods and tools that can be employed by the facilitator. One such tool is inquiry-based learning wherein students will learn science in a way similar to scientists in order to acquire knowledge (Boğar, 2019). Since students are actively involved in an inquiry-based classroom, the teacher becomes a facilitator and their main role would be to guide students through probing questions which leads to queries and discussion. The facilitator does not transfer knowledge, instead probes students to arrive at the concept or phenomenon being discussed (Pedaste et al., 2015). While using the inquiry-based approach, the 'flow' of the lesson plays a key role. The flow would be explained as to how the students are introduced to the lesson, the subsequent order of topics to be discussed and how the lesson is concluded. In the entire flow, it is important that each step is brought through a connect with something that students already know. Hence, following known to unknown format given an added value to the inquiry-based approach. (Gray et al., 2014.; Transforms et al., 2016) In this process, the use of analogies is of tremendous help, especially in classes 6 or 7, during which the students would have just started learning science (especially in the current Indian education system).

An analogy is a useful pedagogical tool in nurturing conceptual understanding in an inquiry-based science learning class. Hofstadter, in his article “Analogy as the core of cognition”, states that “analogy is the lifeblood, …., of human thinking” (Hofstadter, 1976). Analogies help to learn new concepts by relating them to similar examples from day to day life. Therefore the analogies used should be similar to the target (concept being taught), structural similarities or functional similarities (García-carmona, 2020). However, it is very important to mind the use of analogies as they might sometimes lead to misconceptions in students. These misconceptions can go unnoticed by the facilitator and lead to confusion. In order to avoid this, it is essential to teach analogy to students and lead them towards arriving at the intended concept with the use of analogies (Brown & Salter, 2021).

Analogies have been in active use in biology education as well (Treagust & Venville, 2014). There are studies in which facilitators have used analogies to teach topics like cell biology, genetics, molecular biology, biomechanics, enzymology etc. (Brown, 2010; Rix & Learning, 2021)(M. E. Gray & Holyoak, 2021). The use of analogies in biology education is most often seen in higher classes (Dikmenli, 2015). In the Indian education system, according to the NCERT, science education starts in class 6. The curriculum transitions from Environmental science (class 1-5) to science and social science from Class 6 onwards. Students are expected to cope with this transition in studying the actual concepts and laws of science. In this transition state, students would require some extra support to get a hold of the science learning process.

The current study was initiated with the objective of using analogies to enable students to classify plants while teaching the “Plants” module to class 6 students. We were using an inquiry-based learning approach and mainly concentrated on following a known to unknown format. The verbal analogies turned out to be unsuccessful, as the students could not understand the analogy at all. Later we extended our objective to give activity-based analogies and look for its utility in enabling students to come up with plant classification.

METHODOLOGY

Sample

The students (n=29) in the current study are from a rural background, with most of the students being first-generation learners in their families. These kids, even though learning in 6th standard, faced a huge learning gap due to the pandemic and needed extra attention. This learning gap also affected their capability to comprehend the English language at times.

Topic Being Discussed

The chapter ‘Plants’ was being dealt with in the class. In the introductory sessions, the students were asked to ‘picture a plant’ and were taken out to spot different plants that they could see around.

The next objective of the module was to discuss different types of land plants. Also, to understand why they are classified as herbs, shrubs, trees, creepers and climbers. The following was posed towards this objective.

Observe the plants around you and categorize them based on any criteria that you are able to think of. Draw a table including categories and suitable examples.

Verbal Analogies

Upon posing the above-mentioned question, the students were unable to comprehend and hence act on it. This failure led the facilitators to improvise and use certain analogies in the classroom to explain terms like ‘criteria’, ‘basis’, ‘categories’, ‘classify’ and ‘grouping’. Let’s take a walk through how it was done in this set-up:

1. Facilitators spoke about how their class is ‘divided into two groups’ every day ‘based’ on gender.
2. Facilitators also brought to view why the students were wearing t-shirts of four different colours. They were ‘grouped’ based on which team they belonged to at the school, and hence wore different coloured t-shirts.
3. Facilitators also used the ten whiteboard markers present in the classroom and discussed how they can be ‘categorised’ on the ‘basis’ of colours.
4. Facilitators explained the question using the same analogies in students’ mother tongue.

Activity-based Analogies

In the next class, in the attempt to continue with the same approach at the students’ pace, an activity was planned on similar analogies.

1. The class was divided into five groups. Each group was provided with a different sample. The samples used were measuring scales, colours, a deck of Uno play cards, a set of chess pieces and chemicals.
2. The five groups were asked to categorise the samples according to different criteria they could find.
3. Later, a representative from each group was asked to come forward and explain their sample and categorisation to the entire class so that everyone becomes aware.
4. After the discussion, the students were asked the same question again to categorise the plants based on different criteria that they found suitable.

RESULTS:

Verbal Analogies:

Analogy discussed	Students’ response	
	Understanding	**Analogy made?**
Grouping the classroom based on gender	✓	✗
Grouping students based on the house teams in school	✓	✗
Grouping the whiteboard markers based on colour	✓	✗

Table 1: The students’ responses to verbal analogies used in the classroom

Upon explaining all of these again in the mother tongue, it was found that they had already comprehended the statements put across. This explanation made no difference in the outcome from the students’ end. Students understood the statements but could not apply them which is an unsuccessful and incomplete attempt to use analogies. Hence, verbal analogies failed.

Activity-based Analogies

The students' responses to different samples used in the classroom during the activity-based analogies session were as follows (Table 2):

1. Measuring scales: The group having measuring scales categorised them differently based on their length, material and colour (Figure 1).
2. Colours: The group having colours as their sample classified them as markers, colour pens, crayons etc. They also grouped the same colours together (Figure 2).
3. A deck of Uno play cards: The group having Uno cards classified the cards based on colours, numbers on the cards and whether or not it is a special card (Figure 3).
4. A set of chess pieces: The group having chess pieces as their sample classified them based on colour, height, and the types of pieces (Figure 4).
5. Chemicals: The group having chemicals as their sample classified them based on colour and texture (Figure 5).

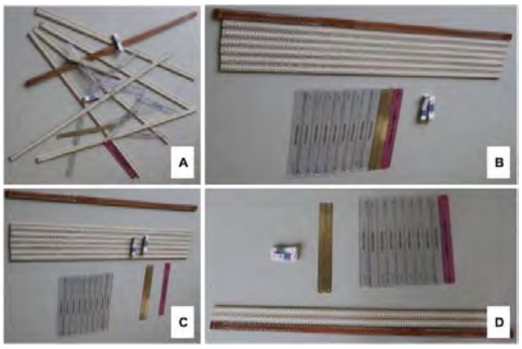

Figure 1: (A) Measuring scales. Students categorized the scales based on (B) length, (C) colour and (D) material.

Figure 2: (A) Colour pens/crayons. Students categorized them based on (B) type/material and (C) colour.

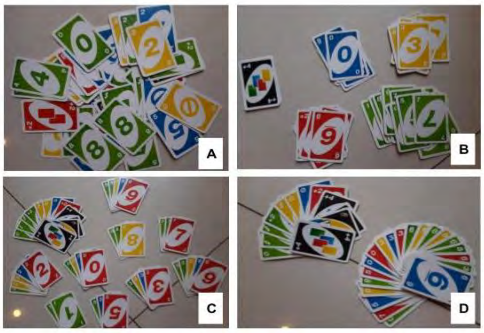

Figure 3: (A) Deck of UNO cards. Students categorized the UNO cards based on (B) colour, (C) number and (D) type of cards

Figure 4: (A) A set of chess pieces. Students categorized them based on (B) colour and (C) type of piece

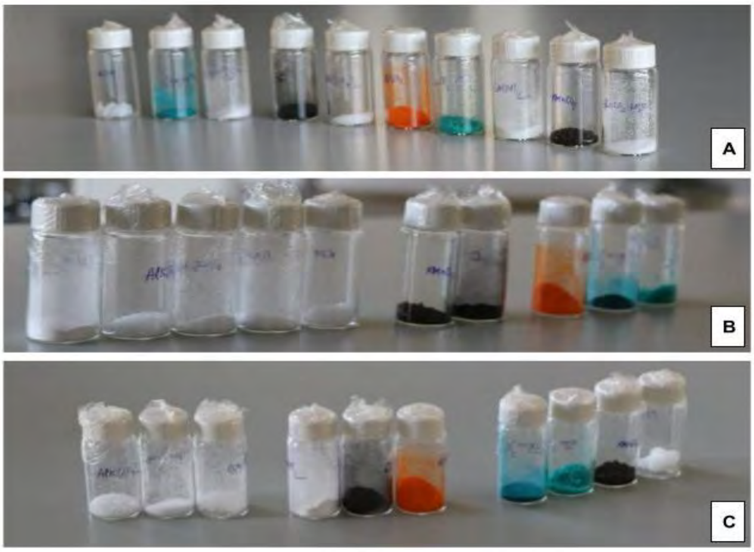

Figure 5: (A) Chemicals. Students categorized the chemicals based on (B) colour and (C) texture

Sample	Expected Outcome	Analogy Made?
Measuring scales	✓	✓
Colours	✓	
A deck of Uno play cards	✓	
A set of chess pieces	✓	
Chemicals	✓	

Table 2: The students' responses to activity-based analogies used in the classroom

After discussion of all the samples, upon posing the question again, the students were able to come up with different criteria to classify land plants. The students came up with categories which are given below:

- short, medium and tall-based on the height of plants,
- fruit-bearing plant or not,
- flowering plant or not and
- thickness of the stem.

This made activity-based use of analogies a success.

DISCUSSION:

Analogies are used in our day to day life, in the simplest of conversations that we have with our family and friends. We use it regularly to make people understand anything that we are talking about. When the same thing is applied in a classroom setup, it enables the students to understand scientific concepts with ease (Keri & Elbatarny, 2021). In the current study, the target groups of students were first-generation learners in their families with a learning gap due to the pandemic. So it was essential to use some thoughtful methods and tools in the learning process of these students. Analogy was one such tool that was tried with these students.

The topic of discussion for this study was "Plants". We see plants every day, everywhere around us. We, as facilitators, were sure that the students would have noticed the plants around them and observed the differences among them. With this in mind, the students were asked to categorize the plants they see around them based on any criteria that they can think of. However, when the students failed to do so, we tried to give them various analogies as mentioned in the methodology. Even after giving several analogies from day to day life, the students were unable to comprehend the question. There are several studies on analogies that have shown that although analogies are useful tools in science learning, the teacher/facilitators should use it with caution (Niebert, Marsch, & Treagust, 2012). There are high chances of students misunderstanding the analogy or, like in our study; the students do not get the analogy at all.

This failure made us reflect upon our strategies and delivery methods and come up with new tools.

Learning is everywhere. Hence, while in a classroom, facilitators and students learn from each other. A teacher or facilitator needs to act right in the classroom and tailor their content based on the students. This is often judged by phenomena like 'feedback'. How the teacher responds to these feedbacks and counteracts is a part of teacher reflection. (Bell & Aldridge, 2014; Craig, 2010; Morton, 2012) Reflection on teacher is what a teacher observes and learns in the classroom and effectuates it in a way that helps the students perform better. (Margolinas, et al, 2005)

After reflecting upon the response that was received for the verbal analogies, we tried to use some hands-on activities as analogies to the question in a discussion. With very little help from the facilitators, the students came up with their own basis for categorizing the samples given to them in more than one way. Now, when the students were probed again to similarly categorize the plants, the students came up with interesting categories as mentioned in the results section. Therefore, although analogies are a handy tool to be used in a science classroom, it is very important to pay attention to the way students understand the analogy and the target concept.

There are several studies reported in literature wherein analogies have been used extensively in a biology class. We would have come across, in a lot of biology textbooks, analogies like "*DNA structure is like a ladder" or "enzyme-substrate reaction is like a lock and key"*(Treagust & Venville, 2014). In a study by Sittichai et al, the authors have used cooking as an analogy for photosynthesis (Wichaidit, 2011). A 2010 study by Simon Brown, Michelis-Menton kinetics in enzymology is detailed using an enzyme-machine analogy (Brown, 2010). Researchers have also developed an interdisciplinary board game analogous to the response generated by the immune system upon encountering a bacterial infection (Cardoso et al., 2008). However, even a simple topic such as classification of plants can be dealt with by analogies. In an inquiry-based classroom, the facilitators try to probe the students to think and come up with the target concepts, like in the current studies. In such a scenario, using activity-based analogies will be extremely helpful in enabling the students to understand and apply analogies to understand the target concepts.

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STRAND 3: PEDAGOGY, CURRICULUM AND LOCAL CONTEXT IN STEM EDUCATION

A CALL FOR MOBILIZING MATHEMATICS EDUCATION TOWARDS GENDER EQUALITY IN INDIA

Mahati Kopparla

University of Calgary, Calgary, Alberta, Canada

She/her/hers

mahati.kopparla@ucalgary.ca

In modern India, gender inequality remains a glaring social issue with women facing rampant inequalities in different spheres of life. Mathematics and statistics literacies play an important role in shedding light on the realities of gender inequalities. Several social campaigns and messaging that targets different women's rights issues are mobilizing critical mathematics literacy and reasoning to communicate their cause. I present some such examples from news articles, academic papers, government campaigns, social initiatives and popular media where mathematics literacy is purposefully used to advocate for women's rights and wellbeing. Through the examples, I identify the potential of elementary and middle school mathematics concepts such as percentages, ratios, proportions, and graphs to explore complex socio-cultural issues. Rather than expecting social change and equality as a by-product of education, there is scope for mathematics education to support critical engagement with prominent social issues.

PROBLEM STATEMENT

In World Economic Forum's ranking based on gender gaps, India ranked 140 out of 156 countries in 2021, indicating rampant inequalities faced by women in four key dimensions: (1) Economic participation and opportunity, (2) Educational attainment, (3) Health and survival, and (4) Political empowerment (Crotti, Pal, Ratcheva, & Zahidi, 2021). Mathematics and statistics literacies play an important role in bringing to light the realities of gender inequalities[3]. Government, inter-government, and non-government organizations utilize mathematical and statistical knowledge for assessments, policies, advocacy and action towards gender equality.

Particularly within the Indian education system, the lived reality of female oppression is represented by categorizing girls as a socio-economically disadvantaged group (Ministry of Human Resource Development, 2020). Through critical and purposeful use of mathematical literacy, numbers no longer remain objective or neutral (Ernest, Sriraman & Ernest, 2016). Instead, mathematics become a humanizing tool to advocate for women's rights, needs and agency. As Indian education system is moving towards adapting the new education policy that advocates for education to "build character, enable learners to be ethical, rational, compassionate, and caring" (p., MHRD, 2020), I explore the opportunities for discussion on gender inequality in school mathematics classrooms.

[3] A note on gender and women: I acknowledge that several individuals lie outside the binary gender identification of male and female. The individuals from communities such as transgender, intersex and gender-expansive face unique challenges and social stigma. In my current discussion of gender inequality, I limit my discussion to issues faced by women.

CRITICAL MATHEMATICS EDUCATION

Mathematics is often viewed as a neutral or objective field. As "colonialism grew together in a symbiotic relationship with modern science, in particular with mathematics, and technology", hegemonic, patriarchal and oppressive values are implicit in dominant mathematics (D'Ambrosio, 1985, p.47). More recently, the competition of international mathematics ranking test such as PISA, has led to teaching and curricular modifications that further alienate mathematics from the local socio-cultural contexts (Sriraman, 2016). While teaching and learning of mathematics is heavily in the pursuit of "varied educational and career options", mathematics has immense potential to support students "to function effectively as citizens" (Ramanujam et al., 2006, p.19). Mathematics can help us make sense of the world or *read the world* and work towards making a meaningful change or *write the world* (Gutstien, 2012). Particularly, critical engagement with mathematics includes recognizing the inherently political nature of mathematics and repositioning mathematical knowledge towards uncovering systems of bias, injustice and oppression in the society (Greer & Skovsmose, 2012). Critical mathematics education is not limited to changing the exiting context of mathematics teaching, but extends to repurposing mathematics as a tool to understand our lived experiences and work towards advocating for ourselves.

EDUCATION AND SOCIAL JUSTICE

In India, as issues of social justice are central to the education system, the New Education Policy states:

> Education is the single greatest tool for achieving social justice and equality. Inclusive and equitable education - while indeed an essential goal in its own right - is also critical to achieving an inclusive and equitable society in which every citizen has the opportunity to dream, thrive, and contribute to the nation. The education system must aim to benefit India's children so that no child loses any opportunity to learn and excel because of circumstances of birth or background. This Policy reaffirms that bridging the social category gaps in access, participation, and learning outcomes in school education will continue to be one of the major goals of all education sector development programmes (MHRD, 2020, p.24)

While being educated is viewed as a source of empowerment, education contexts in schools, specifically in mathematics do not explicitly discuss issues of social justice. Efforts to include diversity and multiculturism in mathematics textbooks remain tokenistic "without critical engagement about issues of difference, discrimination and dominance" (Rampal & Subramanian, 2012, p.72). In this paper, by exploring examples where mathematics literacy was mobilized for awareness and action towards gender equality, I highlight the potential of mathematics education to critically engage with and advocate for social causes.

ADVOCATING FOR WOMEN'S RIGHTS AND THE ROLE OF MATHEMATICS LITERACY

Women in India face inequalities in different spheres of life. Several social campaigns and messaging that targets different women's rights issues are mobilizing critical mathematics literacy and reasoning to communicate their cause. In this section, I present examples from news articles, academic papers, government campaigns, social initiatives and popular media where mathematics literacy is purposefully used to advocate for women's rights and wellbeing.

Value for Life

The predominant patriarchal values in the Indian society have led to a preference for boys and practices of sex-selection such as feticide, female infanticide, and child neglect. India accounts for about 45.8 million or 32% of all missing females in the world due to sex-selection practices (UNFPA, 2020). These numbers depict the grave situation where millions of parents and families perpetuate violence against their babies, solely based on gender. One important indicator of preference for boys is the sex ratio. Building on middle school mathematics topics of ratio and proportions, sex ratio is defined as the ratio of males to females in a population. By comparing the natural sex ratio of 105:100 to the sex ratio in India of 111:100 females at birth, the number of missing females due to pre-natal sex-selection can be estimated. The socio-cultural and geo-political factors associated with sex-selection can be critically understood by observing the changes in sex ratios longitudinally (Sahni et al., 2008), by demographics of the families (Kulkarni, 2020) and spatial distribution of missing children (Guilmoto, Saikia, Tamrakar & Bora, 2018).

Engagement with the sex ratio data reveals alarming trends. For example, Kulkarni (2020) reports that sex ratios at birth are highest among the families with higher education and income levels indicating higher sex-selection practices. This finding directly contradicts the assumption that "education is the single greatest tool for achieving social justice and equality" and highlights the need for more purposeful conversations about gender equality within schools. Further, both Sahni et al (2008) and Kulkarni (2020) demonstrate that the government-imposed ban on pre-natal sex detection failed to create any substantial changes in sex ratios indicating alternate sex-selection practices. Particularly, a spatial distribution map by Guilmoto et al (2018, see Figure 1), provides a picture of the severity of post-natal sex-selection practices across India. These findings further reiterate the need for socio-cultural changes and grassroots movements towards gender equality.

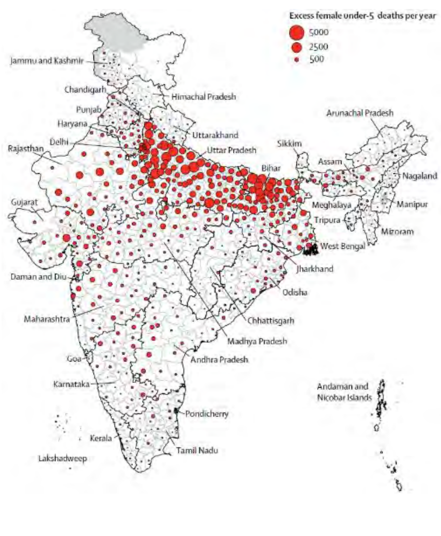

Figure 1. Spatial map of excess female under-5 deaths per year.
Note: Reprinted from "Excess under-5 female mortality across India: a spatial analysis using 2011 census data," by Guilmoto, C. Z., Saikia, N., Tamrakar, V., and Bora, J. K., 2018, *The Lancet Global Health*, *6*(6), e655. Copyright [2018] by the Authors with Open Access under the CC BY-NC-ND 4.0 license.

Dignity of Life

The quality of life for several women could be diminished through their day-to-day interactions and experiences. The rigid gender norms and social expectations in Indian society require married women to prioritize domestic and childcare duties. With working women experiencing higher intimate partner violence to assert domestic dominance (Paul, 2016), many qualified women take on the task of homemaking as their primary profession. As a result, in 2019 only 20.3% of the workforce in India was composed of women (The world Bank Group, 2021). Given the prominent view that domestic work is inferior to work for monetary compensation, the daily efforts of homemakers are invisibilized by family members and the society. The struggle to maintain self-worth and dignity with a lack of economic independence is a daily reality for many women.

In one particular case that contested the amount of insurance settlement provided for the death of a non-earning homemaker, a three-judge panel of the supreme court used mathematical reasoning to assert the value of the unseen contributions of a homemaker. The bench used the Report of the Union Ministry of Statistics and Programme Implementation to note the gender disparity in time spent by men and women on unpaid domestic and care giving services for household members. By critically comparing the time spent by men and women, the bench fixed a notional income for the non-earning homemaker to acknowledge that domestic work is work. Noting the significance and historicity of the judgement in advocating for women, the bench commented:

> It signals to society at large that the law and courts of the land believe in the value of the labour, services and sacrifices of homemakers. It is an acceptance of the idea that these activities contribute in a very real way to the economic condition of the family, and the economy of the nation, regardless of the fact that it may have been traditionally excluded from economic analyses. It is a reflection of changing attitudes and mindsets and of our international law obligations. And, most importantly, it is a step towards the constitutional vision of social equality and ensuring dignity of life to all individuals (Mahapatra, 2021, para. 7)

Health and wellness

Menstruation is a topic associated with socio-cultural stigma, myths, misconceptions and religious restriction in the Indian society (Sinha & Paul, 2018). This leads to unhygienic management of menstrual hygiene, adversely affecting wellbeing, social lives and school attendance of adolescent girls (Garg, Goyal & Gupta, 2012). With about 67% of urban girls and 32% of rural girls using commercial menstrual hygiene products, awareness and access is lacking in rural areas (Van Eijk et al., 2016). To improve access, the government of India has introduced subsidies to make commercial sanitary pads accessible to girls and women in rural regions. To improve awareness around women's reproductive health and hygiene, a video message was issued collaboratively by the National Health Mission, National Tobacco Control Program, and Beti Bachao Beti Padhao campaign (Government of India, 2018).

The video starts with two men meeting in front of a Primary Health Centre, where one of the men is smoking while he waits for his wife to get medical care. The video demonstrates the hesitation of men to discuss about women's reproductive health (excerpt 2 and 12 in transcript 1) and advocates for use of menstrual hygiene products. The use of disposable sanitary napkins is positioned as an affordable option that can prevent dangerous and expensive health issues. Specifically, the argument in the video uses critical mathematical reasoning to compare the monetary value of cigarettes and a pack of sanitary napkins (excerpt 13 in transcript 1) and urges the audience to choose life over death. While the complexity of mathematics in this case is equivalent to grade 1 syllabus, the critical act of comparing the expense for the woman’s need and the man’s want is employed to provoke awareness and social change.

Transcript 1: Transcription of the video message in Hindi with English translation.

1 Man 2: क्या हुआ भाभी को (What happened to your wife?)

2 Man 1: वही औरतों वाली बीमारी (That women’s problem)

3 Man 2: >औरतों वाली बीमारी< (>women’s problem<)

4 Man 1: खर्चा इतना होगया = (The spending is so high)

5 Man 2: = [pointing to the cigarette] cigarette कितने की? (How much did this cigarette cost?)

6 Man 1: [looks confused] (2.) दस रुपये की (ten rupees)

7 Man 2: >दस रुपये की< और जीब में कितनी पड़ी (?) (>ten rupees< and how many more do you have in your pocket (?))

8 Man 1: एक और हे (There is one more)

9 Man 2: मारने के लिए तेरे पास पैसे है लेकिन बीविको मौतसे बचने के लिए पैसे नहीं है (You have money to die, but you don’t have money to save your wife from death)

10 Man 1: क्या बक रहे (What are you blabbing)

11 Man 2: [takes out the cigarette pack from Man 1’s pocket and points to the warning label] यह देख मौत लिखी है इस्पे, मौत! (look, death is written on this, death!)
[points to a pack of sanitary napkins] और इस sanitary pad पे ज़िन्दगी (and written on this sanitary pad is life)

12 Man 1: [laughs nervously and looks away]

13 Man 2: हस मत| दो सिगरेट की पैसे से भाभी को ऐसी खतरनाक भीमारी जो माहवारी के वक्त गंधा कपडा इस्थमल करनेसे हो साथि हे इससे बचा सकता है (Don't laugh, with the money of two cigarettes, your wife can be saved from such a dangerous illness, which is caused by using unhygienic cloth during menstruation.)
और सिगरेट न पीने से अपने आप को भी खतरनाक भीमारी से बचा सकता है (And by not smoking cigarettes, you can also save yourself from dangerous health issues.
यनेकी मौत के पैसे से दो ज़िंदगी खरीद सकता है तू एक अपनी और एक अपनी बीवी की (That means you can buy two lives with the money you use for death, your life and your wife’s life)

REPURPOSING MATHEMATICS LITERACY

As demonstrated by examples of critical mathematics reasoning used to advocate for women’s rights, elementary and middle school mathematics concepts such as percentages, ratios, proportions, and graphs can be extended to explore complex socio-cultural issues. Using these instances and other relevant materials, students and teachers can explore questions such as: (a) Where do you see mathematics being used? (b) How is mathematics literacy contributing to our understanding of the issue? (c) How can we mobilize mathematics to literacy to develop a potential solution to the issues? Extending beyond the notion that "mathematics will never be useful in their lives" (Ramanujam et al., 2006, p.19), students may then begin to observe the relevance of mathematical literacy in understanding and responding to the world around them. Further, by inviting students to explore issues relevant to them using critical mathematical literacy, the mathematics classroom can be transformed into a humanizing and liberating space.

CONCLUSION

Under the pretext of neutrality, mathematics textbooks often focus on calculations and use trivial contexts to introduce concepts and problems. Through some examples presented in this paper, I note that the assumption of neutrality and objectivity of mathematics severely limits the potential mathematics education to contribute to social change. Students have complex out-of-school lives where some of them may have lived experiences of gender-based discrimination. Particularly, school mathematics can provide them the tools to articulate and advance their cause. Instead of creating an isolated space for learning at school, the scope of schools must be extended to build a reciprocal environment that empowers students. Particularly by discussing issues of gender equality, mathematics may become more relatable and accessible to female students, thereby increasing their visibility and participation. Further, the invisibilized patriarchal norms perpetuated through everyday practices and discourse can be critically deconstructed at school and the larger society. While my discussion of gender inequality was limited to three broad areas, the topic of women's rights in India is vast, diverse and complex. Through this paper, my intent is not to focus on specific concerns, but highlight the potential of contextualizing school mathematics through relevant social issues. Rather than expecting social change and equality as a by-product of education, there is a need for schools and educators to actively engage in difficult conversation about social issues.

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A PRELIMINARY STUDY: BEATING THE LINGUAL BARRICADE IN SCIENCE TEACHING FOR UNDERPRIVILEGED STUDENTS

Anamika Sharma[1,a,!], Subhadip Senapati[1,b,#], Athavan Alias Anand[1,b,*]

[1]Department of Chemistry, Prayoga Institute of Education Research (PIER), Bangalore, 560082, India

[a]She/her/hers, [b]He/him/his

[!]asharma@prayoga.org.in, [#]subhadip.senapati@prayoga.org.in, [*]athavan@prayoga.org.in

Inquiry-based learning (confirmatory based approach), has been adopted to gauge the improvements in the students of grade 6 which belong to underprivileged background. The statistical analysis reveals the small but significant improvement among students (measured as P value which was found to be 0.0035 from data obtained in pre-test and post-test). Alongside inquiry-based learning, tag cloud approach also helped in improvising students' ability to beat the language barrier. Altogether, in this study, a significant 1.5 times improvement was observed from pre-test to post-test.

INTRODUCTION

Literacy is an essential component in learning and teaching science and without language acquisition, the development of scientific literacy is difficult (Cohen, 2012). A country like India has this challenge because of the non-English speaking school-age population, multilingual and multicultural family backgrounds (Mohanty et al., 2009). Research has shown that the science concepts taught in a variety of alternative pedagogies helped to break language barriers among primary and secondary school students. Breaking the language barrier among English Language Learners (ELLs) help them to reduce difficulties in learning and enhance their academic achievements. For this reason, there is a need to design some new teaching pedagogies to understand and overcome the learning difficulties of ELLs. According to Seidel and Shavelson (2007), the effectiveness of teaching on learning includes six key components namely Constructive, Domain-specific, Social, Goal-directed, Evaluative and Regulative (Seidel & Shavelson, 2007). This approach resulted in adopting the scientific approach to the teaching method which is widely used to achieve a connection between teaching and learning. Inquiry-based teaching is one of those learning models which develop the attitudes, skills and knowledge of learners in science (Duffy & Raymer, 2010; Small, 2009; Wolk, 2008). Based on the learning process, inquiry-based teaching (Figure 1) is broadly classified into (i) confirmation inquiry, (ii) structured inquiry, (iii) guided inquiry and (iv) open inquiry (Spronken-Smith & Walker, 2010).

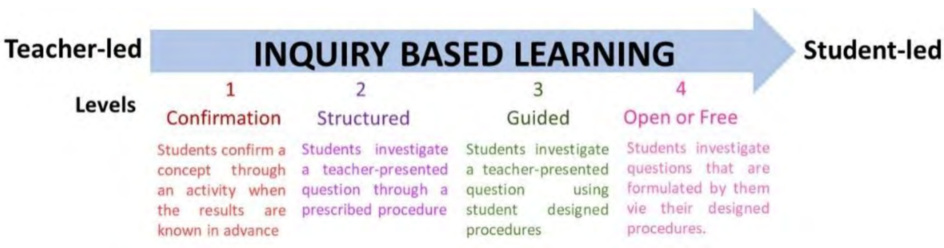

Figure 1. Inquiry based learning pedagogy with different levels of learning.

Inquiry-based learning (IBL) is constructivist and student-centred teaching method that enhances students' motivation and engagement throughout the course of the learning process (Cavallo et al., 2004; Suppapittayaporn et al., 2010). We used the confirmation inquiry-based learning (CIBL) method to teach the basic concepts of Matter, where the teachers provide open questions, investigation methods and the expected outcomes to the students and the student duty is to perform the given activities to attain the desired results. The successful research studies made the CIBL practices an increasingly popular teaching model at lower grades in school environments. Moreover, inquiry learning requires students to engage in metacognition which allows them to develop problem-solving skills and draw conclusions. In addition, Experimental Learning Theory (ELT) originally proposed by Kolb was also considered while designing our learning modules. ELT states that learning is "the process whereby knowledge is created through the transformation of experience" (Kolb, 1984). Further, ELT explains the learning process in two stages i.e., grasping experiences and transforming experiences (Kolb et al., 2014). Based on these learning processes Kolb learning cycle consists of four parts: concrete experience (CE), reflective observation (RO), abstract conceptualisation (AC) and active experimentation (AE). According to Kolb learning cycle, learning begins when students engage in specific experiences (CE) and the reflection on that experience (RO) leads them to draw scientific conclusions (AC). Later, the students perform some activities (AE) to test the scientific concepts which serve them new experiences (CE) to continue the cycle. The above learning cycle allows students to think and develop new ways to solve problems. Basically, chemistry is a subject that deals with the characteristics, composition, structure and chemical reactions of the substances. Researches reveal different types of teaching approaches were employed to increase students' performances in chemistry learning (Stieff, 2005; Wu & Shah, 2004). In the present work, we tried to enhance the conceptual understanding among non-English speaking first-generation learners by following the experiential ways of learning incorporated with the confirmation inquiry-based instruction approaches. This student-centred learning design allows students to explore their own ideas and develop independent thinking. Also, gives opportunities to students to practice communicating science with peers and teachers. Socio economically disadvantaged children were selected from a rural school and the learning sessions were conducted in separate well-equipped classrooms designed by us. To evaluate the efficacy of our designed pedagogy, a few subtopics from the Matter topic were taught to grade six students and we tried to understand their obstacles in learning science due to the language barrier.

METHODOLOGY

Classroom Facilities

The smart classroom is well equipped with modern facilities as shown in Figure 2. The classroom is equipped with the digital displays, whiteboards, aiding listening devices, and other audio/visual components that make lectures more interactive. Students were organized inside the classroom in group of 5 on each table. The idea of group was incorporated to promote self-learning in addition to assisting other students on the respective table. The idea is found to be beneficial for any learning level in education (Hammar Chiriac, 2014). Inquiry-based learning pedagogy arranges student ability to question, think ideas and analyses the data obtained (Banchi & Bell, 2008; Bayram et al., 2013). Generally, students will remote background find it quite challenging compared to students of average or above average background. Therefore, inquiry-based learning strategy to found to be fruitful in training students compared to traditional teaching methods.

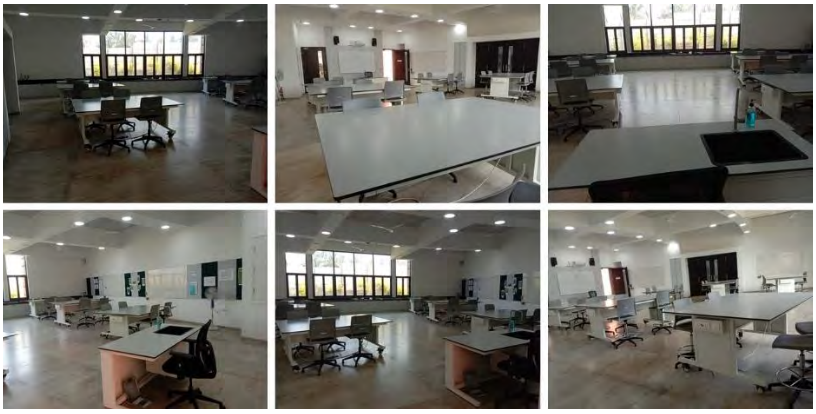

Figure 2. Smart classroom for this preliminary study.

Course Description

A group of 24 government school students of grade 6 were involved in this study. The sample set of students was from an underprivileged background which limits their communication skills and need a special teaching approach in science instruction. Keeping their background in mind, for the purpose of study, only a section of “Matter” module was included. “Matter” is a subject wherein experiments were designed to explain the concepts to students with visual changes which makes the understanding of subject viable for students. Prior to the study, their content knowledge was evaluated in the form of a pre-test which included three categories of question viz., multiple choice questions (MCQs), true and false (T&F) and fill in the blanks (FiB). These three categories of questions were selected to evaluate students’ ability to decide, predict and test their subject knowledge. After the completion of a section from “Matter” module, a post-test was conducted to evaluate the improvement in the learning process. Both the tests (pre-test and post-test) involved similar categories of questions as mentioned earlier.

The study was conducted to assess their progress during the learning process by comparing pretest and post test results via statistical data. The content of the module was taught using inquiry based (hands on experiences that lead to exploration and high-level questioning) as well as experiential learning (hands on experiences that provide evidence about phenomena in the world). The module covered following sections during teaching:

1. What is matter? State different types of matter.
2. Concept of atom.
3. Concept of dilution.
4. Demonstration of changes in states of matter from solid→liquid→gas.
5. Idea of compressibility and its behavior in different states of matter.
6. Concept of density, fluidity, viscosity and fluids.
7. What is inter-particle distance and inter-particle force?
8. Effect of inter-particle distance and force in different states of matter.

All these concepts were taught keeping in mind student’s learning disability due to poor language skills. A total of 12.5 hours were used to teach the above concepts which include the test time of 30 mins in the last session for assessment to check the progress/improvement among the students. The statistical analyses were carried out to evaluate students’ learning outcomes using Prism 6 software (GraphPad, San Diego, USA). The t-test was used to check the statistical significance between the data by the computing the P-value. P-value less than 0.05 was considered to be significantly different.

RESULTS AND DISCUSSION

From student's perspective, inquiry-based learning pedagogy promotes investigating a question or problem allowing them to use evidence-based reasoning/problem solving capacity to obtain conclusion. On the other hand, from facilitator's end, this pedagogy promotes learning in students beyond general curiosity leading to critical thinking and understanding (Bayram et al., 2013; Capps & Crawford, 2013). Out of the four main types of inquiry-based learning(confirmation, structured, guided and open-inquiry) there is no fixed set of data (or rules) to which type of pedagogy needs to be implemented (Banchi & Bell, 2008; Capps & Crawford, 2013). In the current study, confirmation-based teaching was adopted during the teaching in classes. Statistical analysis of the students from underprivileged backgrounds was studied by conducting a pretest and a posttest (Krzywinski & Altman, 2013). The pretest consisted of four MCQs, one T&F and two FiB type of questions to assess their content knowledge from previous traditional teaching methods. The average marks (absolute) calculated from the evaluation of pretest was found to be 27.8±16.0. The set of questions were designed keeping the level of grade 6 students. However, many spelling mistakes, and lack of understanding of question (poor answering capacity in the pre-test it was evident that these students lack in their understanding of concepts due to their deprived background (Figure 4). It was observed that language was another major barrier. Lack of understanding of questions was quite evident from the analysis. Being from such a background, a confirmation inquiry-based learning strategy was adopted which is the basic step in inquiry-based learning approach (Banchi & Bell, 2008; Bayram et al., 2013). The confirmatory based approach allowed the facilitators to explain the concepts to these students more conveniently. The facilitator developed questions of a topic followed by designing of activity which led the students to learn the concept by performing the activity. In parallel, several attempts were made to improve their vocabulary. Tag clouds generate visual images which emphasize the most frequently used words during the learning process in each class (Kim et al., 2014). They allow students to focus on the words used frequently in the class and thus, act as memory jogger when students are revising for examinations (Jayashankar & Sridaran, 2017; Kim et al., 2014; Miley & Read, 2011; Zan et al., 2015). Owing to the advantages, tag clouds were introduced to students at the end which included the new words learnt by them during each class. This list kept growing with the further classes (Figure 3). Also, students were made to explain the meaning of new words taught to them during the class. This exercise was further extrapolated to involve students for writing the meaning of the respective word on the board (this was to encourage them to develop writing skills alongside improving the vocabulary). Being from underprivileged background posed a serious limitation in training them (as more than 80% were the first-generation learners). Therefore, a mixed approach (which includes language barriers, vocabulary, learning disability, inquiry-based learning and experiential learning) was adopted to train these kids initially, in order to bring a comfortable zone for these kids for developing interest towards science learning.

This was a qualitative study which reflected improvements from pre-test to post-test.

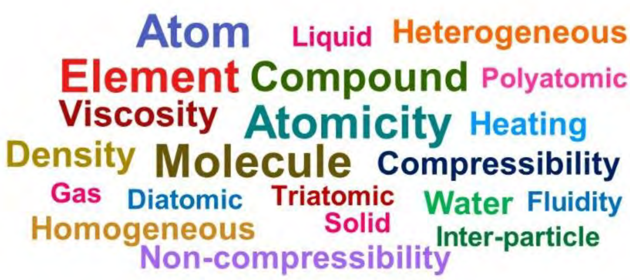

Figure 3. Tag cloud for the "Matter" module to improve students' vocabulary (Kim et al., 2014; Zan et al., 2015).

The teaching was then implemented which taught "Matter" based on the subtopics mentioned in the methodology. Each subtopic was taught involving activity. The series of activities performed are tabulated in Table 1.

Sl. No.	Activity	Learning Objectives
1	Activity 1.1-1.3	Understanding of concept of mass
2	Activity 2.1	Understanding concept of volume
3	Activity 3.1*	Understanding tiny particles forming matter & concept of dilution
4	Activity 3.2*	Understanding about atoms
5	Activity 3.3*	Presence of different atoms in different atoms
6	Activity 1.1*	Understanding change in different states of matter
7	Activity 1.2	Understanding concept of compressibility
8	Activity 1.3	Understanding concept of fluidity and viscosity
9	Activity 1.4	Concept of viscosity and density are independent
10	Activity 1.5	Concept of fluidity in different states of matter
11	Activity 1.6	Understanding inter-particle distance in states of matter

*Activity was demonstrated.

Table 1. Details of activities performed to teach "Matter" module.

To begin with the confirmatory inquiry learning, students were allowed to experience that solid, liquid and gas have masses by doing hands-on activities with clay (solid), water (liquid) and air (gas). Each student was allowed to perform the activities using weighing balance. Performing activities facilitated the understanding the concept of matter. Demonstration of activity 3.1, 3.2 and 3.3 was adopted as it involved the use of chemicals like potassium permanganate, potassium dichromate and copper sulphate for safety of students (Figure 4).

To improvise the understanding of the concept, videos were played to inculcate the relevant concepts. Videos thus played the bridging gap between facilitators (teaching methods) and activities performed (Box et al., 2017; Pasquali, 2007; Sonmez & Hakverdi-Can, 2012). Videos were mainly based on the basic concepts of atoms, matter, states of matter and how inter-particle force and distance in case of solid, liquid and gas can be visualized. The further hands-on activities engaged and motivated students throughout the classes. The final conclusion from the activities was documented in the activity sheets which trained students in skills like observation, experimental skills, collecting and processing data.

Figure 4. Demonstration of activities 3.1, 3.2 and 3.3; explaining the concept of dilution. a) Dilution in potassium permanganate solution for the entire class; b) and c) for individual table (for clear observations in color change from purple to pink upon dilution).

The confirmatory based approach helped in improving the knowledge and problem-solving capacity of students. Students after each activity showed interest in learning further concepts with same enthusiasm and motivation. Therefore, to assess their progress, a posttest was conducted which consisted of similar set of questions (three MCQs, three T&F and four FiB) to assess their content knowledge after implementing confirmatory inquiry-based approach. The average marks (absolute) calculated from the evaluation of posttest was found to be 41.9±17.9. Upon comparison of the pre-test and posttest, it was observed that there has been a significant increase in the average (1.5 times) in a short duration of learning process (Figure 5).

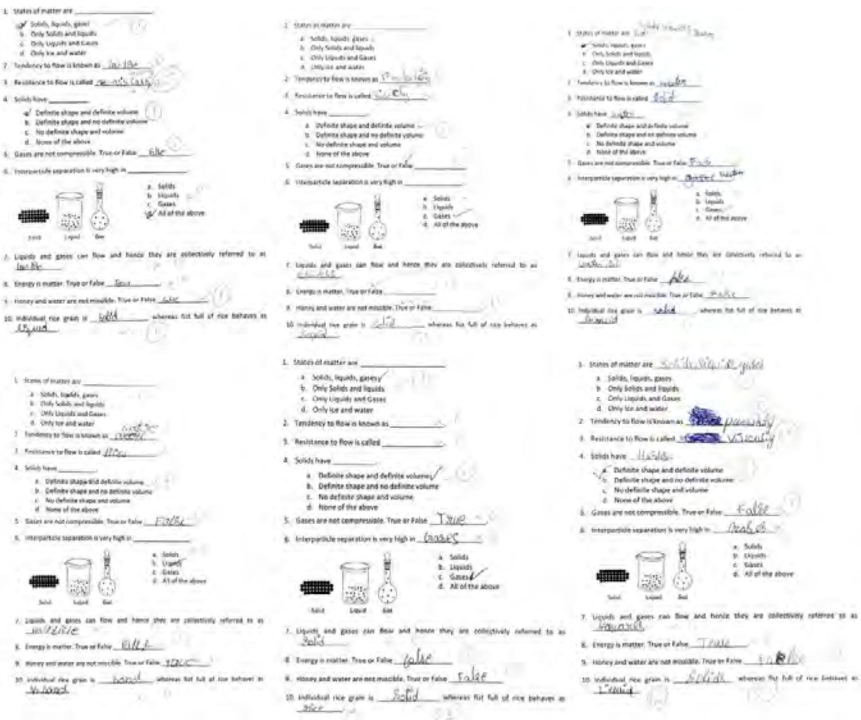

Figure 5. Students' responses to posttest (depicting improvement in vocabulary hence in better understanding of questions asked compared to pre-test).

Figure 6 shows the increase in the average score after the intervention. The clear shift of distribution of the individual scores towards higher percentages from pre-test to post-test was reflected in the increase of average score. To check whether the improvement in scoring was significantly different, t-test was used for both sets of data (pre-test and post-test) and P-value was computed. P-value was found to be 0.0035, implying the change was significantly different and students' understanding of the topic improved notably.

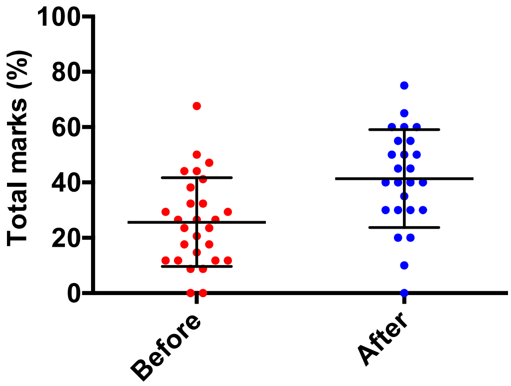

Figure 6. The average score increased from 27.8±16.0 in the pre-test (red) to 41.9±17.9 in the post-test (blue). This increase was found to be statistically significant by t-test (P-value = 0.0035)

The major limitation of this study is a small sample test (n=24). But even with small basis set, the positive results obtained motivated facilitators to incorporate confirmatory based teaching strategy in the completion of course. This teaching approach (compared to traditional methods) requires a longer time which remains a limitation/challenge for the facilitators. However, bearing the positive outcome of the study, this strategy will be implemented further for the same set of students (to evaluate the progress). In addition, owing to the progress made by the students so far, a switch from confirmatory based approach to structured based inquiry will be implemented in the next phase (as described in Figure 1).

CONCLUSION

In summary, the research reveals the positive improvements in the students of grade 6 which belong to underprivileged background. In order to adopt strategy to explain science it was evident to incorporate strategies to improvise their English. This was achieved successfully via tag cloud approach and making them write the meaning of new words learned in each class. Quasi-experiment design and comparison of pre-test and posttest depicts significant 1.5 times improvement in the growth of students towards learning concept of "Matter" via inquiry-based learning. In the current study, although confirmatory based approach was adopted which will be improvised to structured based approach after observing significant changes among students which will be implemented in future.

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AN EXPLORATION OF PROFESSIONAL NOTICING AND PCK (PEDAGOGICAL CONTENT KNOWLEDGE) AMONG TEACHER EDUCATORS FROM LOW RESOURCE COUNTRIES

Anirudh Agarwal[1, !], Arushi Bansal[1, #],Ruchi Kumar[1,*]

[1]Tata Institute of Social Sciences, Mumbai

[!]anirudhagarwal8@gmail.com, [#]bansal.arushi17@gmail.com, [*]ruchi.kumar@tiss.edu

Little research is done with the teacher educators of mathematics in order to understand their knowledge of subject specific and topic specific PCK. Given that this knowledge is claimed to be essential in supporting students' learning, it is important to understand the nature and extent of this knowledge among the teacher educators. This study analyses responses of 17 teacher educators from low resource countries to understand their beliefs about teaching, their knowledge of general pedagogy of teaching and their subject specific and topic specific PCK, specifically in response to student difficulties described in the case presented. It is observed that though many teacher educators exhibit student centered beliefs about teaching mathematics and have a good understanding of the subject specific PCK, they have a relatively weak grasp of topic specific PCK and pedagogic strategies to address student difficulties to teach algebra.

INTRODUCTION

There are numerous interventions and continuous professional development programs as well as a growing body of research and scholarship towards building the capacity of teachers in teaching mathematics in the classroom. However, there is scant research about the kinds of beliefs and knowledge of the MTE (Mathematics Teacher Educators) as well as those identifying the directions in which efforts are required for MTEs' own professional development. Math educators have proposed the need for MTE to have meta-PCK (Beswick and Chapman 2012) to understand the knowledge of the teacher and what is useful for learning mathematics for the students. There are limited avenues through which this meta-PCK can be gauged. This paper uses a case study to analyse the professional awareness of MTE signifying skill of professional noticing and the meta-PCK amongst teacher educators of Bhutan, Nigeria, Tanzania and India.

THEORETICAL FRAMEWORK

We align theoretically with ideas proposed by Beswick and Chapman (2012) about the knowledge of MTEs, in identifying PCK as an important part of knowledge required by teachers and hence by teacher educators. Shulman (1986) identified (PCK) as a knowledge that teachers use to transform the mathematical knowledge while addressing students' difficulties and misconceptions in learning the concept. Thus, PCK governs how to teach and what to teach. It also involves understanding conceptual and procedural knowledge of students, students' alternative conceptions and levels of understanding as well as techniques to diagnose and assess students' learning and misconception. Ball et al. (2005) included PCK as an important part of mathematical knowledge for teaching which includes explanation, understanding and examining students' work for which different forms of representation is required, for instance being able to use models or examples. The teacher should be able to build on and bring a relationship between these different forms of representation. These connections have mathematical underpinnings where teachers come up with strategies of using models, examples, sequences and so on for students. Veal and MaKinster (1999) further describes the taxonomy of the PCK where general PCK, domain specific PCK and topic specific PCK are intertwined and essential for the teacher to understand classroom discourses, perceive students' knowledge and their way of thinking, as well as subject specific content knowledge. Beswick and Goos (2018) argues that MTEs need meta PCK so that the teacher educators not only have the knowledge of the teachers' understanding but also what is useful for the students of the teacher and will help in learning mathematics.

We propose that along with PCK, MTEs need to be able to have same or higher level of professional awareness (Mason, 2011) by being able to notice and "identify relevant aspect of a teaching situation; use knowledge to interpret the events, and establish connections between specific aspects of teaching and learning situations and more general principles and ideas about teaching and learning" (Llinares, 2013). Having the skill of professional noticing requires being able to identify the mathematical elements in the pedagogical situation, interpret students' response and make informed decisions.

This paper uses the framework of PCK and professional awareness in combination to analyse the nature and extent of knowledge and awareness that MTEs exhibit when they are presented with a case describing student characteristics.

METHODOLOGY

The particular test case analyzed in this paper is a part of a sample course Reflective teaching of Geometry as part of CL4STEM project with the larger goal of building capacities of middle and secondary school newly qualified teachers (NQT) in science and mathematics for fostering inclusive higher-order learning in their classrooms. At the first level the focus is on developing teacher educators' pedagogical content knowledge through engagement in design-based thinking and creating modules for NQTs. 17 teacher educators from Bhutan, Nigeria, India and Tanzania participated in the testing of the sample course by engaging as a student. The descriptive response to the following question was submitted by the teacher educators as part of the course. Informed consent for using submissions for research purposes was taken prior to starting the course. Given below (Box 1) is the question that was posed.

> *Fela loves making different objects and figures using paper. Yesterday, he made a swan and an equilateral triangle by folding paper. In the mathematics class, he finds it difficult to understand the meaning of algebraic symbols and is not able to solve any quadratic equations. When he gets the question paper, he selectively attempts those questions that do not involve algebra.*
>
> *How would you, as a teacher, help them in learning mathematics?*

Box 1: Question posed to teacher educators under the test case

The analysis of responses were done qualitatively through "directed content analysis" (Hsieh & Shannon, 2005) using codes derived from the theoretical framework used for MTE knowledge discussed in earlier sections. The responses of 17 TE were downloaded and analysed by three researchers (authors) independently on four parameters: Teacher Educators' beliefs, Teacher Educators' knowledge of pedagogy, Teacher Educators' knowledge of student thinking and whether the pedagogy lent to addressing the student specific characteristics/difficulties mentioned in the question. A consolidated summary for each response was aggregated from responses of the researchers and the few discrepancies in the analysis were resolved through discussion. Thereafter, the consolidated summaries were analyzed for evidence around teacher educators' beliefs about learning, their general and subject (math) specific pedagogy and topic (algebra) specific PCK. The consolidated table of responses was created and the different types of responses for each category were analysed for similarity and contrast to identify the different perspectives about teaching of algebra to the particular child 'Fela' as mentioned in the question.

RESULTS

The TEs who participated answered, with a varying degree of alignment with each other, and to the general pedagogical principles. Given below (Table 1) is a consolidated data about the responses that they provided. The table provides a summary of responses, but is not to be used for drawing generalisations given the small sample size. The table must be read in conjunction with the qualitative discussion of data that follows and forms the central pillar of data analysis. In the table below, some of the responses fell into more than one category and therefore the total number of responses for a particular category is more than 17.

Response details	**Number of TEs (%)**
Teacher beliefs / general pedagogy	
Recognised student's preferred way of learning and interests	8 (47%)
Recognises the affective struggles and advocates mitigating them	2 (12%)
Believes in presence of multiple intelligences among students	1 (6%)
Subject (Mathematics) Specific Pedagogy	
Believes that hands-on learning / learning using concrete / experiential learning / Mathematics learning connected to real life is important and can be useful.	8 (47%)
Believes that multiple mathematical representations can be useful.	2 (12%)
TE advocates for student agency by allowing them to use their own methods and symbols while doing mathematics.	2 (12%)
Topic (Algebra) Specific PCK	
Outlines activities for teaching generalization (topic specific PCK)	2 (12%)

Does not address pitfalls of using completely new set of symbols	2 (12%)
Does not outline a topic specific PCK	11 (65%)
Outlines a topic specific PCK misaligned with subject specific pedagogy	1 (6%)
Outlines a topic specific PCK but is not clear on how it will help student learning	4 (24%)

Table 1: Consolidated table of responses and their frequency

As per the data collected one will see that 47% (8 out of 17) respondents exhibit a positive belief about student learning which takes into account the student interests and preferences. 47% (8 out of 17) TEs identified the preferred learning style of the student as well as the activities that the student enjoys, and proposed considering that while designing the intervention. TE1' response acknowledges that Fela is a tactile learner who does not like symbolic representations and abstract representations, and hence, the teacher must move to adopt more concrete approaches, and TE 17 advocates for using the student's interest in making swans to be used in teaching algebra. It was also seen that TE 4 identified that Fela enjoys playing with objects and making figures with paper, and thus this predilection must be utilised in the classroom for teachers. Furthermore, TE 12 identified Fela to be a tactile person, suggesting that concrete methods of teaching must be used.

> From the situation described above, Fela is a tactile learner who does not like symbolic representations and abstract representations. For Fela to succeed in learning Mathematics, teachers should adopt the following approaches to teaching. - TE 1
>
> As a teacher, if Fela loves playing and makes different objects and figures with paper, then we should understand algebra can also be taught in a similar manner so that the child builds his/her interest. - TE 4
>
> Fela seems to be a creative person, who likes playing with objects. He is a tactile person. - TE 12
>
> To help Fela with the understanding of Algebra, we will use his paper made swan and equilateral triangle to represent our algebraic symbols - TE 17

Not only were some TE sensitive to the learner's learning style, some TEs also exhibited an understanding of affective factors affecting student learning. TE 2 and TE 5 provide some evidence of the respondents being sensitive to the consequences of the difficulties that the student face such as an increase in student anxiety and propose that these affective reactions must also be mitigated in the classroom. TE 5 also showed an acknowledgment of multiple intelligences in the way they answered.

> In the scenario above, I think Fela is quite an intelligent student. Building a swan and an equilateral triangle by simply folding a paper would not be a cup of tea for me. It would definitely require a skill set to do it. Yes, Fela has some mathematical conscience and does understand some basic algebra and unknowingly, he has applied these ideas in his paper folding technique. He has failed to recognize these basic algebraic ideas in him. - TE 5

However, there was an instance where a TE also advocated for using repetition as a key to mastery, thereby suggesting a deviation from the accepted learning theories of the subject. TE 9 exhibited a belief that repetition of concepts and practice is the key to mastery. Here, the respondent did not suggest interventions to improve student's understanding using the concrete methods or incorporating the student's preferred way of learning or their interests.

> Fela is good at geometry because she always practices making objects and draws figures. To help her in algebra, the teacher should encourage her to make a lot of practice in algebra by giving her more questions of the sort. - TE 9

Overall, 71% (12 out of 17) respondents exhibited a strong grasp of general pedagogy or math specific pedagogical content knowledge. This included a knowledge of connecting learning to real life, and creating a fear free classroom.

Some TEs, however, went a step further and showed subject specific (mathematics) pedagogical knowledge. 47% (8 out of 17) TEs professed using concrete artefacts to enable student learning, a technique specific to enable mathematics learning, before moving on to abstract understanding and problem solving, using hands-on activities and moving from knowledge of the known to unknown.

> Sometimes (it) is easy to learn mathematics by starting with what is known to (the) unknown. To teach Fela you can start with what he like(s) and know well which geometry is. As a teacher you can start teaching algebra by adding and subtracting of tangible things before you go to symbols - TE 7

> Since Fela is a tactile person, teaching with models (3D or Pictorial will help him understand the concept. Use of teaching materials or concrete will help students construct the concept meaningfully. - TE 12

12% (2 out of 17) TEs showed evidence of using "multiple representations" wherein the same problem is solved using different ways, including concrete and abstract. This evidence points to the respondents' fairly strong grasp on the general pedagogy of teaching the subject. An example of TE outlining use of multiple representations is given below.

> We can also teach Fela to solve the quadratic equations by using different methods like graphical methods, elimination methods and other algebraic methods. We can also teach algebra by using the concept of triangles like sum of angles in a triangle, perimeter of triangles and so on - TE 3

Though the respondent above has outlined topic specific PCK (using graphical and elimination methods), overall the respondents' knowledge of the topic specific PCK is seen to be wanting. Though the respondents in some occasions advocate for using general mathematical principles as outlined above, 65% (11 out of 17) TEs did not clearly outline how the pedagogy will be effectively applied in the context of teaching algebra. 24% (4 out of 17) TEs outlined a topic specific PCK but were not clear on how it will help student learning and 6% (1 out of 17) TEs outlined a topic specific PCK misaligned with subject specific pedagogy. Given below is an example where TE 12 advocated using concrete artifacts (subject specific pedagogy) but was unable to outline how it would be used for the specific topic in question.

> Fela seems to be a creative person, who likes playing with objects. He is a tactile person. Well, algebra needs (a) deeper understanding of the content and representing the meaning in symbolic form. This requires critical and analytical thinking, which Fela would find difficult to interpret and represent. Since Fela is a tactile person, teaching with models (3D or Pictorial will help him understand the concept. Use of teaching materials or concrete will help

students construct the concept meaningfully. - TE 12

Even though the respondent says that concrete methods must be used to ease learning of abstract algebra, the respondent does not outline what exactly that concrete strategy will look like. In another example, the TE 14 gave the following answer.

> I will teach Fela with objects instead of the traditional way of writing on the blackboard alone. I would explain the concepts using figures which I ask him to make himself. This will enhance his learning. - TE 14

TE 14 exhibits the knowledge of using concrete artifacts, or figures made by students themselves, for teaching but do not outline what the figures will be or how they will be used in instruction.

We have not presented disaggregated data by countries as it would be unfair to generalize about the MTEs of particular countries based on the small number of MTEs that took part in this exploratory study. On the whole, one may say that though the respondents exhibit a positive belief and general and subject specific pedagogical content knowledge, they seem to have a weak grasp on topic specific PCK.

Discussion

Like teachers, teacher educators' beliefs also play an important role in their approach towards mathematics teaching and learning. However, since all the four countries have undergone curriculum reform in recent years, the MTE's response indicates awareness and alignment towards student-centered teaching approaches that may be diverse. The analysis of their responses with respect to their skill of noticing student characteristics and their difficulties, and being able to suggest pedagogic strategies in alignment with the student interests, building on what they already know, was found to be challenging for most of the MTEs. The responses show that the differences lie in the attention to the details and knowing topic specific representations and pedagogic strategies. This points to the need for building topic specific PCK among MTEs. We aim to engage the MTEs in a design thinking approach for creating modules for teachers of their countries for difficult topics and support reflection through research reading, curriculum analysis, collaborative discussions, trials of proposed activities for teachers and its redesign.

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ANANDI: USING PRINT MEDIA TO REACH THE UNREACHED DURING THE PANDEMIC AND BEYOND

Asmita Redij[1,a,~], Arnab Bhattacharya[1,b,!], Megha Chougule[1,a,@], Vikrant Ghanekar[1,b,#], Suravi Kalita[1,a,$], Sarita Kamat[1,a,%], Vijay Lale[1,b,^], Shweta Naik[1,a,&], Vikram Patil[1,b,*], Harita Raval[1,a,&&], Pritesh Ranadive[1,b,^^], Uzma Shaikh[1,a,$$], Sai Shetye[1,a,%%] and Aniket Sule[1,b,##]

[1]Homi Bhabha Centre for Science Education, Tata Institute of Fundamental Research, Mumbai 400088, Maharashtra, India.

[a]she/her/hers, [b]he/him/his

[~]asmita@hbcse.tifr.res.in, [!]arnab@hbcse.tifr.res.in, [@]meghac@hbcse.tifr.res.in, [#]vikrant@hbcse.tifr.res.in, [$]suravi@hbcse.tifr.res.in, [%]saritak@hbcse.tifr.res.in, [^]vdl@hbcse.tifr.res.in, [&]shweta@hbcse.tifr.res.in, [*]vikram@hbcse.tifr.res.in, [&&]harita@hbcse.tifr.res.in, [^^]pritesh@hbcse.tifr.res.in, [$$]uzma@hbcse.tifr.res.in, [%%]sai@hbcse.tifr.res.in, [##]anikets@hbcse.tifr.res.in

The effects of Covid-19 and subsequent closure of schools for nearly two year period have robbed many children of their basic Right to Education. Particularly in the marginalized sections of the society, where education is the only hope for a better future, this break from education could potentially wipe out hard earned gains over several years. For most of these students, closure of schools meant no access to education or educational material beyond textbooks. Many villages still don't have phone networks or the internet, so online education is not an option. To address this new challenge to the education system, we returned to an old paper media, a Newsletter or just a letter, to interact with the students. We named this newsletter Anandi[4], meaning 'blissful'.

In this work we will discuss the genesis and design of the newsletter, and the learnings from our experiment. We emphasize the need to scale up such efforts during the pandemic period to complement the efforts taken by the schools and other educational bodies. We also briefly present opinions of students and teachers about such an intervention.

INTRODUCTION

Several agencies conducted formal and informal surveys following the nationwide lockdown early on in the COVID-19 pandemic. It brings forth a disturbing picture of online/remote education models (APF, 2020). The surveys showed that more than 3/4th of rural students lacked the resources to participate in remote education (PARI, 2021). Over ~20 months (since February 2020) into schools' closure, most rural students were deprived of any form of scholastic learning. As schools reopen, we are seeing the first formal indicators of this invisible crisis in terms of the number of students who choose not to return to school (Ramanujam, 2021; Gupta, 2021). The drop-out rate for girls is much higher than that of boys. This data is supported by independent surveys, which indicate a significant rise in marriages of underage girls in rural

[4] The name ANANDI also honours the inspirational life of Dr. Anandibai Joshi, one of the first women from India to study modern medicine.

areas (Chakraborty, 2020; Wylie, 2021).

The students who did manage to return to the schools had an uphill task of understanding concepts from a higher school class, even though they had missed essential prerequisites which were supposed to be covered in previous classes during the past months (Mishra, 2020; APF, 2021). As the learning deficit piles on, there is a real danger of more students being compelled to drop out soon.

During the pandemic, access to textbooks was also rare. Also, students only have textbooks of the present year as the previous years textbooks are collected back by the school. So there was an urgent need to reach out to students without access to online education in remote/tribal regions. As the learning crisis for this student population primarily arises from a lack of access to modern tools, we turned to the old media, i.e. a paper newsletter sent to the students.

In this paper, we describe the conceptual framework, design process and learnings, findings which corroborate the need for such endeavours and future implications of such design to address immediate concerns of post-pandemic education in remote rural regions in India.

CONCEPTUAL FRAMEWORK

To address the above concern we followed a Design-Based Research methodology (Wang, F., Hannafin, M., 2005). The work of development of the theme, formation of a collaboration to actual newsletter roughly went through the following design process of Empathize, Define, Ideate, Prototype, and Test/Implementation (Henriksen, D.,Richardson, C., Mehta, R., 2017).

Empathize: The children from rural, mostly tribal regions or those of migrant workers were away from education for a major period during the pandemic, as online education was not a viable option. Many of them were tied up to farming and related activities, and some worked as daily wage labourers or helped with other household chores. Hence the children of the age group of 13-15 years are more vulnerable to school dropout, either compelled to consider earning opportunities or as they succumb to the post-pandemic classroom challenges (Redij, A. & Sule, A., 2022) like learning loss, weak foundation etc.

Define: There was a need to rekindle interest in formal schooling and inspire them, particularly girl students, not to abandon education. To bridge the learning gaps, which can be done by connecting Science/Mathematics with their experiential world. Moreover, to give them exposure to the world outside and showcase opportunities they can avail through education. The aim was to complement the efforts taken by teachers, school and the educational fraternity in these difficult times.

Ideate: The schools selected primarily serve the children from tribal regions or those of migrant workers in different parts of Maharashtra. The target audience were the students from the age group of 13-15 years, as the dropout rate is higher post 8th grade. Since the online means of connecting were not a viable option due to limited resources, paper media was chosen as a means of reaching students. A newsletter was started to address their immediate fears and concerns related to education.

Prototype: This newsletter was designed in the form of personal science communication and was intended to cater to the academic and emotional needs of the students. In the first pilot phase, four newsletter issues were sent to a few schools at an interval of one and a half months each. Starting from 225 students from 6 schools in Gadchiroli, Hingoli, Palghar, and Raigad districts of Maharashtra, from the third issue onwards, an 8-page coloured newsletter is reaching nearly 2500 students from 22 schools each month. The newsletters were mailed by ordinary post in bulk to the teachers of these schools, who helped with the task of hand-distributing them to the individual students.

Implementation: Starting from January 2022, a newsletter with the name 'Anandi' is being sent to 35+ schools from different districts of Maharashtra, reaching 4000 students. In designing the content described below, we follow a non-linear, reflexive and iterative method based on the learnings from the responses received from students and through teachers interaction.

CONTENT DESIGN, PROCESS AND LEARNING

The content for the newsletter is designed keeping in mind the students who are first generation school goers[5], with no academic support at home (particularly during lockdown when they are away from school). We constantly ensured contextualisation of the content, situated in students' experiences and culturally responsive. In the following subsections we describe how these factors governed the design process of the content.

The language of communication.

We chose Marathi as the language for communication which is the medium of instruction at the selected schools in Maharashtra. However, it was also vital to keep the context of the language in mind as formal Marathi is not the language spoken at home by most of the target audience. For this, whenever possible, we emphasised colloquial words, avoided formal/complex words and often considered local contexts. The style of address was deliberately kept lucidly informal as in a personal conversation.

Style of communication.

Considering that most of the target students spend their time on farms, rearing cattle, etc. the topics of the articles and the examples were situated on children's experiences. We deliberately chose an *activities-based* design, which was carefully based on the resources around the students so that they could connect to their experiential world. These activities had concrete observation plans to facilitate a guided enquiry process.

The write-ups were often written as stories or dialogues. For example, in Fig 1, one can see a simple story of a king and a clever village girl to illustrate the idea of geometric progressions, where magnitude increases rapidly. The king, who thought of the girl's demand for rice as trivial, soon realised its enormity. And that he might have to empty the royal storage to complete the demand. As the target students have seen rice stocked in jute sacks (*goni),* they can easily relate to the amplification of the quantity in exponential functions.

[5] We deliberately use the term 'First Generation school goers' rather than the more popular phrase 'First Generation learners', since learning has always happened, even out of the formal school system.

Fig 1: Illustration of exponential function activity

Illustrations.

Illustrations were liberally interspersed within the text, making the articles inviting and comprehensible. Some write-ups also continued characters such as *Mukta,* a fearless, thoughtful village girl who uses mathematics efficiently.

Student-response sheet.

The newsletter included a response sheet which the students could post back to us. The questions were designed to help students connect the new concepts in the articles to their experiences. Further, students handwritten responses helped us connect with them; learn more about their language usage, culture and surroundings.

SCIENCE AND MATHEMATICS CONTENT

The Science and Mathematics content is aligned to the syllabus of the 8th to 10th grade, though not being strictly confined to it. Care was taken not just to deliver information, but also to acquaint them with aspects of the nature of Science, encouraging them to *observe*, *inquire*, and *reflect* upon what they see, and most importantly, *ask questions*. For example, Fig 2 illustrates a dialogue between two friends, a school girl student and her older friend. The dialogue proceeds as the young girl inquires about the flashing light in the sky, and how her questions and misconceptions regarding shooting stars are clarified.

> आनंद आणि तेज ही तितकंच पाहण्यासारख होतं. त्यानंतर बराच वेळ मुद्दाम अंगणातले दिवे विझवून आम्ही अजून एखादा तुटता तारा दिसतो का हे पाहत आणि रात्रीच्या आकाशातील असंख्य ताऱ्यांना न्याहाळत बसलो. पण आम्हाला तुटता तारा पुन्हा काही दिसला नाही.
>
> माझी बालमैत्रीण काहीशी निराश दिसल्यामुळे, मी तिला सांगितलं की "नोव्हेंबर महिन्यात 6 ते 30 तारखेदरम्यान तुला असे बरेच तुटणारे तारे पाहायला मिळतील, अगदी पाऊस पडल्यासारखे. आपण तेव्हा पाहू या." ती खुश होऊन टाळी वाजवणार इतक्यात काही तरी बिनसल्यासारखी जराशी नाराज झाली, "ताई सगळे तारे पडून गेले तर त्यानंतर रात्रीच्या आकाशात तारे दिसणारंच नाहीत का गं?" आता मला हसू आवरेना, "अगं, ज्याला आपण तुटता तारा म्हणतो तो तारा नसतोच. ती उल्का असते" मी सांगितलं. अर्थातच तिचा पुढचा प्रश्न तयारच होता, "उल्का म्हणजे काय गं ?"

Fig 2: Discussion around Shooting Stars

We balanced our coverage of topics in Science and Mathematics with sections from the humanities, covering the history of scientific discoveries, stories of inspiration and resilience from Social Sciences. Special care was taken to connect to the emotional world of the children addressing their fears and concerns pertaining to education during the pandemic time.

FINDINGS AND CONCLUSION

Two important design features of the newsletter were local context and interactivity. The concepts (whether in Science or Mathematics) which were new to the students were introduced with the help of examples of local relevance, from their immediate surroundings. As the example in Fig 3, the concept of 'Photoperiodism' is introduced. The students were encouraged to write back to us about their own related experiences. Students in their responses have confirmed having observed such phenomenon before, giving examples.

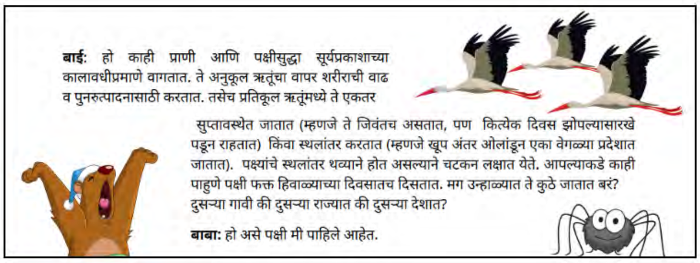


Fig 3: Seasons and Animal Behavours

Teachers/school authorities at the grassroot level had alerted us of some of the difficulties with typical learning materials (both curricular and extracurricular) that marginalised students face. The inappropriateness of examples/activities outside the context of students' lives was pointed out by a school Principal,

> "My school serves children of migrant workers. Students don't respond when they don't connect to the content. Like if they are asked, 'share your experience visiting a pizza shop'. What will they write, if they have never experienced going to one?"

She added

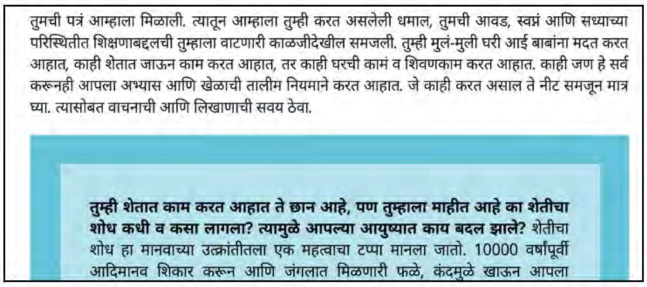
> "After the lockdown some recommended teaching science through kitchen activities, the houses of my students were struggling getting enough food during this lockdown. How then can we discuss science through this mode"

This newsletter gives these students a chance to express themselves and open up. In responses sent to us, the students shared their small pleasures, the work they did while at home, their aspirations, and some expressed concerns regarding their educational goals. As one student wrote, "I am very sad, I had a goaI to play sport and play at national level in athletics but the practice was discontinued during the pandemic." . Other wrote,

> "I wanted to complete my graduation, after finishing 10th from present school, but due to corona everything has come to a halt. I want to be a teacher and teach children from the village."

The content has been shaped by students' responses and teachers' inputs. It has allowed us to reflect and refine the content at every level (whether language or concept), be sensitive to the present situation and their needs, or make the content contextual by valuing their experiences and sharing ideas to try different things (refer Fig. 4). Students responses to these have been encouraging,

> "I liked the idea of how students came together to build a library (when schools were closed)', 'Like the students in the story even I get many questions throughout the day', or 'The story of Anandi(happy) students reminded me of the fun I had with my friends?"


तुमची पत्रं आम्हाला मिळाली. त्यातून आम्हाला तुम्ही करत असलेली धमाल, तुमची आवड, स्वप्नं आणि सध्याच्या परिस्थितीत शिक्षणाबद्दलची तुम्हाला वाटणारी काळजीदेखील समजली. तुम्ही मुलं-मुली घरी आई बाबांना मदत करत आहात, काही शेतात जाऊन काम करत आहात, तर काही घरची कामं व शिवणकाम करत आहात. काही जण हे सर्व करूनही आपला अभ्यास आणि खेळाची तालीम नियमाने करत आहात. जे काही करत असाल ते नीट समजून मात्र घ्या. त्यासोबत वाचनाची आणि लिखाणाची सवय ठेवा.

तुम्ही शेतात काम करत आहात ते छान आहे, पण तुम्हाला माहीत आहे का शेतीचा शोध कधी व कसा लागला? त्यामुळे आपल्या आयुष्यात काय बदल झाले? शेतीचा शोध हा मानवाच्या उत्क्रांतीतला एक महत्वाचा टप्पा मानला जातो. 10000 वर्षांपूर्वी आदिमानव शिकार करून आणि जंगलात मिळणारी फळे, कंदमुळे खाऊन आपला

Fig 4: Dialogue with Students – Student letters

During one of the school visits by one of the authors to a school where the newsletters reached, a few girls flocked around, and asked "Did you get our letters? We liked reading it. Do send us more."

The feedback we have received has convinced us of the value of such an initiative at these times. Collectively, we are working towards developing a repository of content which is not just inclusive but is developed with the last child in focus.

IMPLICATIONS

While Anandi, with its tagline "EduReach: to reach the unreached" started as an initiative to reach out to under-served students amidst the pandemic, the responses suggest a more remarkable impact well beyond this. Such a newsletter can also serve as an important real-world testbed for STEM education research. An analysis of the student/teacher responses feeding into the development of content that is inclusive and responsive to the needs of its audience can provide necessary inputs into the STEM education initiatives that are focused on under-served and marginalized communities.

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DEVELOPING INFORMAL INFERENTIAL REASONING: EVIDENCE FROM RURAL AREA IN PALGHAR DISTRICT

Mitali Thatte[1!] and Nilesh Nimkar[1#]

[1] Quality Education Support Trust

[!]mitali.thatte@quest.org.in, [#]nilesh.nimkar@quest.org.in

This paper describes two activities related to statistics education, one conducted with a child in grade one and one conducted with children in grades 6 and 7. These activities were based on the literature in statistics education but adapted to suit the local context so that they are culturally appropriate. Based on the idea of Informal Inferential Reasoning, neither of the activities introduced any formal ideas about statistics to the children, they relied on building an intuitive sense of the big ideas of statistics like mean, variance, confidence interval etc. Children in the sample resided in rural part of Palghar. They had good foundations for Language and Mathematics but lived in an environment where mathematical or statistical language was not used regularly. Even then, we saw that it was relatively easy for the children to grasp the inherent uncertainty in interpreting data and children from both the activities were able to deal with this uncertainty. They were able to make inferences based on informal reasoning. These activities serve as a proof of concept of the potential of introducing statistical thinking to children at an early age even to children who live in an environment which is largely devoid of the necessary mathematical and statistical language.

BACKGROUND

The importance of using and interpreting data has been increasing in the last few decades. Phrases like ‘Data is new gold’ are frequently heard in many conversations related to jobs and careers. Responding to the growing need of literacy about data and statistics, the field of statistics education at school level has expanded rapidly in the past couple of decades (Ben-Zvi , Makar, & Garfield, 2018). There has been extensive research on different components of statistical inference like articulating problem, planning data collection, sampling, data gathering, data analysis, data representation, summarizing and reducing data, drawing informal conclusions, statistical literacy, learning through full cycle of statistical investigations. (Ben-Zvi , Makar, & Garfield, 2018)

In Maharashtra, the importance of Statistics is reflected in the curricular framework proposed for students of all grades. One of the important mathematics curricular expectations for children in primary grades is to collect, represent and interpret simple data from her/his contexts and use it in everyday life (CurrExp). Two curricular expectations for students of upper primary grades are 1) to learn to provide reasoning and convincing arguments to justify her/his own conclusions in mathematical context and 2) to collect, represent (graphically and in tables or charts) and interpret data/information from her/his life experiences. The following table enlists the grade-wise learning outcomes for primary and upper primary grades (Grade 1 to Grade 8) expected in statistics along with the most complex examples for that particular grade found in the school textbook.

Grade	Learning Outcome	Example from the textbook

2	draws inference based on the data collected such as the number of vehicles used in Samir's house is more than that in Angelina's.	Given a list of months and a list of students who have their birthdays in that particular month, answer questions such as, 'Who all have birthdays in January'.
3	records data using tally marks, represents pictorially and draws conclusions.	Given is a table with tally marks for the number of children who like different sweets. How many more children like Jalebis than Gulabjamuns are the type of questions asked.
4	represents the collected information in tables and bar graphs and draws inferences from these	There is a given dot plot (discrete bar graph) of the frequency of three different flower plants in Payal's garden. 'How many plants of Type 1 are there in Payal's garden are the type of questions asked.'
5	collects data related to various daily life situations, represents it in tabular form and as bar graphs and interprets it.	Draw a bar graph based on the table given below
6	arranges given/collected information such as expenditure on different items in a family in the last six months, in the form of table, pictograph and bar graph and interprets them	Examples of simple interest and complex interest
7	interprets data using bar graph such as consumption of electricity is more in winters than summer, runs scored by a team in first 10 overs etc.	Calculate the frequency table for the number of members of each family for a set of 50 families.
8	draws and interprets bar charts and pie charts.	Given a join bar graph of jowar and wheat, calculate the percentage of wheat produce and percentage of rice produce, calculate

Table 1: Gradewise curricular expectations for data and statistics.

We see a strong focus on interpretation of data in all the learning outcomes. However, children are not expected to experience different aspects of statistics like defining the question, sampling, planning for data collection, predicting the future etc. either at a formal or informal level. Even with this caveat, the learning outcomes can be called sensible but the examples that we see in textbooks do not really match up to the expectation of drawing inferences from the given data. From the examples given in the textbook, one can infer that the word 'interpretation' has been interpreted as 'being able to read the graph' or to go back and forth between representations rather than drawing conclusions based on the graph. Just going by the curricular expectations, the focus is only on interpreting the given charts and tables. In statistics education the word 'inferences' generally means using data to form an opinion or using data to predict the future. Statistics as defined by the American Statistical Association is the science of learning from data, and of measuring, controlling and communicating uncertainty. This is not reflected at all in the examples in the textbook

For example, the following graph summarizes the weather conditions recorded by students of a particular school for a particular week in the month of September.

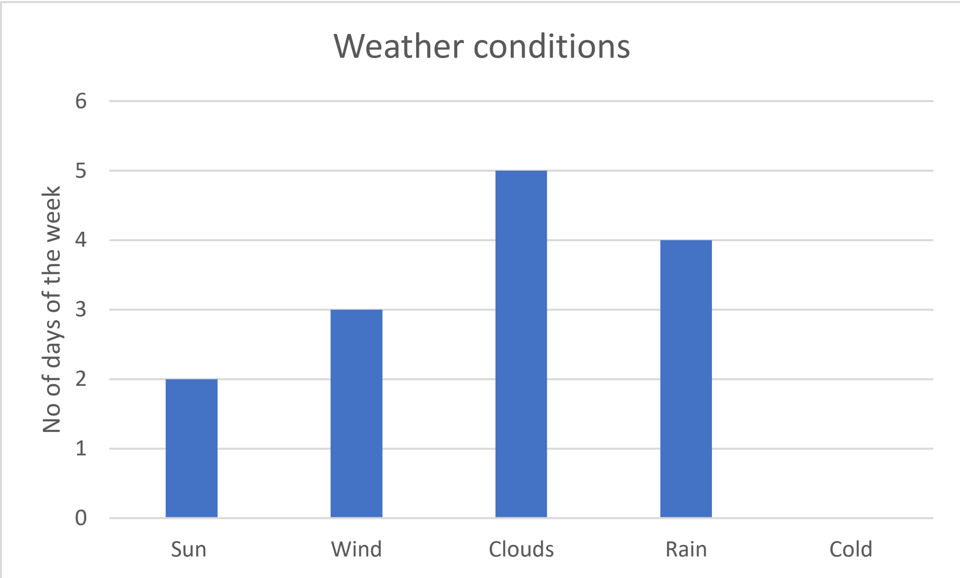

Figure 1: Weather conditions for a particular week.

The graph can be read as; "we could see the sun for two days in that week". Textbooks generally ask questions such as "For how many days did it rain". However, asking such questions is useful only to check if the child has understood the graphical representation. They do not really ask the child to interpret the data. For this, we should ideally ask questions like:

1. Can we say that the weather was generally cloudy for that particular week?
2. Is it likely that it won't rain at all next week?

The questions illustrated above do not ask the child just to read the graph. They ask the child to use the information in the graph but go beyond the graph to make some statements about the real world. It is important to note that the child is not expected to calculate statistics like mean or standard deviation in order to understand and articulate the inferences that we can make based on the data. This has been called as Informal Inferential Reasoning (IIR) (Zieffler, Garfield, Delmas, & Reading , 2008). There are various concepts in statistics like mean, standard deviation, frequency, mode, outliers, distributions etc which can be developed in children using informal inferential reasoning. (Pratt, Johnston-Wilder, Ainley , & Mason, 2008). Research shows that children can reason about the big ideas in statistics at an early age thus building the base to learn the concepts formally. Informal inferential reasoning is completely absent in the school textbooks. In our experience this results in children associating ideas like 'mean' only with the formula given in the textbooks and do not understand that mean is a measure of central tendency and has a significance in the real world.

This paper provides some examples of activities conducted for students of different grades with a focus on the informal understanding of key concepts of statistics like central tendency, variation, distributions etc. The activities are inspired by the literature available in statistics education (English, 2012) (Makar, 2013) and have been developed by the authors keeping the local context in mind, with the aim of giving children an experience of the full cycle of statistical inference which includes Problem, Plan, Data, Analysis and Conclusion (MacKay & Oldford, 2000). These activities have been conducted for children of different grades. Bhumi (name changed) was in grade 1 while Sameer, Neha and Bhaskar (Names changed) were in grades 7 and 8.

ACTIVITIES

Activity 1: How many peanuts can fit in this cup?

Bhumi (name changed), a girl in Grade 1 and the authors conducted an activity to see how many peanuts fit in a cup. The cup was filled by scooping the peanuts in the cup from a large bowl in one go and not by filling the peanuts one by one in the cup. The cup was small and was carefully chosen so that about 25 peanuts would be able to fit. It was established beforehand that Bhumi was able to count at least up to 50. At the beginning of the activity the researcher posed a question to Bhumi.

Researcher: We have to see how many peanuts fit in this cup.

[The researcher told Bhumi that she has to fill peanuts in the cup and then count them. Bhumi filled the cup with peanuts.]

Researcher: How many peanuts do you think there are in this cup?

Bhumi: 10

[The researcher and Bhumi counted the peanuts. There were 23 peanuts in the cup. They noted the number in their notebook and filled the cup again.]

Researcher: How many peanuts do you think there are in the cup this time?

Bhumi: 31

Researcher: You guessed 10 last time, why did you guess 31 this time?

Bhumi: Because last time there were actually 23 peanuts in the cup. This time there will be more than 10?

[There were 24 peanuts in the cup]

The following table summarizes Bhumi's Guess as well as the actual number of peanuts which fit the in the cup during every trial.

Trial Number	Guess	Actual number
1	10	23
2	31	24
3	20	25
4	18	23
5	15	20
6	20	25
7	16	19

Table 2: No of peanuts that fit in the cup

Bhumi guessed that there would be 20 peanuts for trial 6.

Researcher: Why do you think so?

Bhumi: Because there were 20 last time (in trial 5)

[After the completion of the activity the researcher and Bhumi discussed their findings.]

Researcher: What do you say, how many peanuts fit in this cup?

Bhumi: 23… 24… 25

Researcher: Why?

Bhumi: Because 25 fit twice and also 23 because they fit twice.

Researcher: Will 30 peanuts fit?

Bhumi: No, because they did not fit even once.

Researcher: 22?

Bhumi: Yes.

Researcher: Have 22 fit any time? No, right? So why do you think that 22 will fit?

Bhumi: If we do it again they will come.

Researcher: If we do it again will 30 fit?

Bhumi: No

Researcher: So from how many to how many peanuts will fit?

Bhumi: 23, 24. 25, 23, 20 25, 19

It is very likely that Bhumi did not understand the question posed by the researcher because she was unfamiliar with the terminology 'from how many to how many (साधारण किती ते किती)'. The researchers then decided to demonstrate how to use this such terminology.

Researcher: Can I say that about 50-100 fit?

Bhumi: No

Researcher: 31-40?

Bhumi: No

Researcher: 8-10?

Bhumi: No

Researcher: So what can we you say?

Bhumi: 23 – 25 (will fit)

We can see the formation of the notion of some form of central tendency in the reasoning of Bhumi. Although the range of the observations is from 19 to 25, she did not say that 19-25 peanuts fit in the cup. Even when she was primed with ranges like 51-100, she stuck to her answer of 23-25. She was able to ignore the 19 and the 20 as the outliers. It is important to note that Bhumi is in Grade 1 and has had no exposure of statistics or data previously. A hypothesis would be that it is her lack of exposure to formal notion of range that allowed her to think correctly beyond traditional notions of 'Lowest value – Highest value' thus demonstrating the necessity of exposure to informal reasoning before introducing formal terms. It is important to note that Bhumi did not initially understand the phrasing 'From how many to how many' that was used by the researcher. The researchers had to model how to use such uncertain language accurately. In the rural/tribal context that Bhumi is a part of, such modelling may also have to be one of the objectives of activities in statistics education.

Bhumi also demonstrates intuitive understanding of the concept of variation in the data. Even though she recognized that 22 peanuts have never fit in the cup, they might fit if we run the experiment again but 30 peanuts will not fit.

Activity 2: Throwing Balls in a Bucket

Context: There were three children Sameer, Neha and Bhaskar (names changed) of grades 6 and 7 who were present for this activity. These three students were told that there is a hypothetical competition titled 'throwing balls in a bucket' for a cluster of ZP schools. Every competitor gets 10 throws with a ball. The person who gets the ball in the bucket for the highest number of times wins. One child per school will represent the school at this competition. The researcher would be recommending one child amongst the three children to participate in the competition. The researcher told the children that they had to help him decide and posed this question to the children; "How will you decide who amongst you will go to the competition."

Sameer: We will practice

Researcher: But how will you decide whether you will be able to win or not?

The children then started thinking about the conditions in which the competition would take place for example. Would it take place outside or inside, how far would the bucket be from the thrower, how big the ball would be etc. The researchers then provided all of this information to the children.

Bhaskar: Now we will know how many times the ball will go.

Researcher: How will you know; can you tell me?

Neha: If we all come in one place, if Sameer goes first, if I go second, if Bhaskar goes third, we will know who should go for the competition.

Researcher: If you do that and Bhaskar wins, will you be able to say definitely that Bhaskar will win during the competition as well?

Sameer: If Bhaskar's ball goes all the time, then we can say that he will win.

Researcher: So does this mean that it won't be enough to do the trial run only once? How will you decide?

Neha: What if all of us throw the ball ten times out of ten?

Researcher: Do you think that, that will happen?

Sameer: Maybe 1 or 2 of us can hit 10 out of 10 but not all three of us.

Researcher: So can we say that the probability is low? (Marathi word शक्यता for probability was used)

Researcher: Okay, so Neha was saying that we should do and see. What exactly do you mean by that?

Sameer: Different (number) of balls can go at different times. So we would have to do it a lot of times.

The children then started throwing the balls in the bucket one by one. They were also maintaining the data (in their notebooks) while doing so. The children performed the trial 10 times. The following is the data for the 10 trials. Every child got 10 chances per trial to throw the ball in bucket and the children recorded the number of times the ball actually went in the bucket out of those ten chances. The children had decided in the beginning that they would conduct 10 trials with 10 chances in each trial.

Trial	Sameer	Neha	Bhaskar
1	3	3	7
2	5	2	5
3	6	2	5
4	4	5	6
5	5	2	6
6	5	5	5
7	5	4	6
8	6	3	6
9	3	5	5
10	5	8	3

Table 2: Ball throwing activity

The following is a conversation that happened between the children immediately after the children had recorded the data in the table for the last trial

Bhaskar: Neha won. [Referring to the value 8 for Neha in the last trial which is the highest number of hits]

Researcher: So, should we send Neha to the competition?

Bhaskar, Sameer, Neha: No

Researcher: Why?

Sameer: The eight won't come every time.

The children were intuitively able to understand that the 8 for Neha is an outlier but were unable to articulate the logic behind their thinking. The children were then shown how to draw a scatter plot of the given table.

This is an image of the scatter plot that the children had drawn.

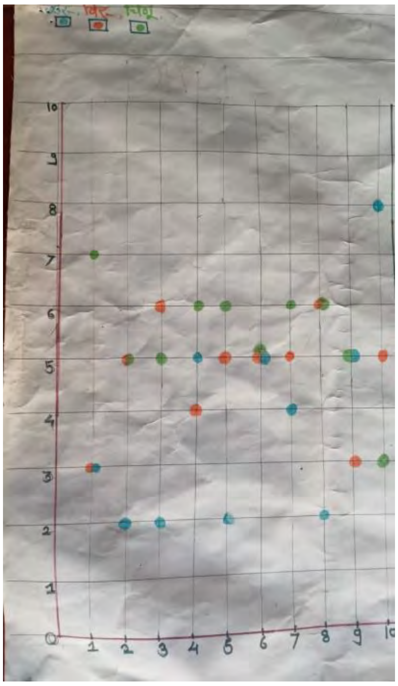

Figure 1: Scatter plot of throwing ball in the bucket. Blue dots are for Neha, Green for Bhaskar and Orange for Sameer.

The researchers showed the children how to interpret the scatter plot. The children spent considerable amount of time discussing about the individual data points like Neha's eight. The researchers had to model how to read the scatter plot as a whole. To do this, the researchers asked questions like "Can we say that Sameer generally throws the balls in the bucket more times than Neha does?" or "Who is more reliable, Bhaskar or Sameer?". While addressing the second question, the children, with the help of the researchers discussed how being reliable would look like on the graph and were able to arrive at the conclusion that if the points for an individual person are spread out more, you will be able to predict how that person would perform with low accuracy. Therefore, that person would be less reliable. The researchers also asked some questions to children like would reliability be the only factor to consider while sending someone to the competition. For example, if a person throws the ball reliably in the bucket about 3 times out of 10, should that person be considered for the competition. The children were able to reason correctly that it is both the reliability and the value around which the points are scattered which will determine who will go to the competition. Although the formal terms were not introduced, children were able to understand that it is both the mean and the variance which will determine who will go to the competition.

The following is a conversation that took place towards the tail end of the activity after the children had spent about 15 minutes discussing the scatter plot in detail.

Researcher: Tell me why did we draw the graph?

Neha: We can see how far I am spread out. I have thrown the ball three times as well as 8 times. I won't win.

Researcher: So, what can you say about the players?

Bhaskar: Everyone is throwing between 4 to 7 balls.

Neha: Bhaskar is more reliable. He is less spread out. He will win.

We can see that the children have developed an informal understanding of various concepts of statistical and scientific thinking. They have understood the importance of asking the right questions like how far is the bucket from the competitor. If the questions are framed well, only then can we get the desired information. They have seen the value in collecting data and of repeated data collection. Especially after drawing the scatter plot, the children looked past the individual data points to read the graph as a whole and developed an intuitive sense of the concept of variance and of ignoring outliers like Neha's eight. The activity can be described as a full cycle of statistical investigation.

DISCUSSION

From the above activities, we can see the potential for reasoning about data that students demonstrate. It goes well beyond the expectations made from the students by the textbooks. For example, in grade 7, the curricular expectation is "interprets data using bar graph such as consumption of electricity is more in winters than summer, runs scored by a team in first 10 overs etc.". This expectation is limited to making inferences about the available data using mean or some other central tendency. However, the examples in the textbooks do not really meet this expectation. Even at the level of the learning outcomes the importance of variability is effectively ignored. The inferential reasoning demonstrated by the students from the above two activities show the potential for understanding and communicating ideas like mean, variance, standard deviation, outliers etc. Students are able to understand complex ideas like variability at an informal level. Students were also able to understand the need for collecting data which is also another largely ignored area in textbooks. (J. Michael Shaughnessy, 2002). It is important to note that these activities were conducted with students living in rural areas of Palghar and although they have had better schooling than many of their peers, they can be categorized as privileged students of an underprivileged area. Although the activities could be conducted successfully in terms of achieving their overall objective, a lot of modelling and linguistic scaffolding was needed even for effectively using terms like 'about 15'. After such scaffolding was provided, children were able to use sentences "the probability of scoring a 10 every time is low" when previously they would have used sentences like deterministic sentences like "the ball won't go 10 times". In urban areas, probably such activities can be conducted with greater ease although we suspect that a lot of linguistic scaffolding will still be necessary. Further research is necessary in order to explore the degree to which these ideas can be formalized and applied to real life context.

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EXAMINING THE EFFECTS OF TEACHERS' SELF-EFFICACY IN TEACHING ASTROPHYSICS USING VIDEO-BASED MULTIMEDIA

Gabriel Janvier Tugirinshuti[1 *], Leon Rugema Mugabo[1 #], Alexis Banuza[2 !]

African Center of Excellence for Innovative Teaching and Learning of Mathematics and Science (ACEITLMS) of the University of Rwanda-College of Education[1]

Université de Burundi. Institut de Pedagogie Appliquée. Departement de physique-Technologie.

Centre de Recherche en didactique des disciplines et de diffusion des sciences (CRDS) [2]

[*]tunshutigj@gmail.com, [#]mugabol2000@yahoo.com, [!]abanuza@yahoo.fr

Today, more than ever before, video-based multimedia is integrated and has become a significant portion of the present life, and its speedy development is enhancing the education system. Information and communication technology (ICT) video-based multimedia is also essential for schools, and hence for teachers' pedagogical daily activities. Conversely, not every teacher has the skills to teach using ICTs video-based multimedia. The present study reported a qualitative research design that examined the effects of teachers' self-efficacy in teaching and learning physics using ICTs video-based multimedia. In this study, we purposively select nine physics teachers of age between 30 and 40 years from eight scientific secondary schools found in the Rutsiro and Rubavu districts, Rwanda. Semi-structured one-on-one interviews and class observation were used to collect data. Collected data were analyzed using the content analysis method. Results revealed that factors that affect teachers' self-efficacy are divided into two categories: intrinsic and extrinsic factors. Moreover, the results of this study revealed how those identified factors related to the usage of ICTs video-based multimedia in teaching physics. The results provide evidence of the need for more attention to how the identified factors could be addressed.

Keywords: ICT, Self-efficacy, teaching and learning physics, Video-based

INTRODUCTION

Physics plays an imperative role in society as it enhances research and thrives in medicine, technology, engineering, et cetera. In recent past years, Rwanda's educational goal of increasing a knowledge-based and technology-led economy pushes educators and policymakers to develop competitiveness in science, technology, and mathematics education (REB, 2015). Mastery of basic scientific and mathematical ideas makes learners confident in problem-solving and increases their critical thinking. However, a recent study revealed that the development of educational systems at different periods of time is linked to variations in each age because the educational system should reflect the education needs of society in that period (Gingell & Winch, 2008).

Educators know that ICT tools are accessible for their educational activities. However, due to different reasons, some teachers do not benefit from the prospect of incorporating such tools into their classrooms (Özdemir, 2017). Recent studies by Wastiau et al. (2013) and Guo et al. (2012) have reported some causes for underused ICT such as lack of training, poor infrastructure, policies aiming at promoting ICT use, teachers' personal beliefs, and teachers' lack of self-efficacy in integrating ICT in teaching and learning activities.

Drawing from Bandura (2006) self-efficacy refers to someone's beliefs and competencies to organize and implement action. Self-efficacy stems from the social cognitive theory and takes an important place in the behavior one chooses to reveal (McCormick, 2001). Therefore, referring to the predictive power that self-efficacy has on personal beliefs and behavior, examining factors that affect it and desired behavior makes sense. Moreover, examining teachers' ICT self-efficacy and issues that affect it is one way to offer educational leaders the information they need. Self-efficacy influences teachers' technology and finally enhances its use in their school activities.

LITERATURE REVIEW

According to Bandura (2004) and Burdick (2014), the theory of self-efficacy alludes to someone's beliefs in one's skills to arrange and perform the sequences of work vital to bring out given achievements. Bandura (2004) showed that self-efficacy stands at the center of the social cognitive theory that looks to the possible positive effects on the way persons understand and interpret their proficiency and competencies in a field of concern such as teaching and learning. Bandura (2006) reported that self-efficacy in a particular domain affects individuals' thought developments, levels of determination, and degrees of incentive and influences individual performance. Hatlevik (2017) revealed that in education, a teacher's self-efficacy is in line with the belief in his/her competencies to carry out desired outcomes of learners' commitment and knowledge even among those learners who may be inattentive. Recent studies reported that teachers' self-efficacy affects satisfaction, professional commitment (Caprara et al., 2006), and important forecaster of learners' incentive and achievement (Guo et al,. 2012). Moreover, teachers' self-efficacy refers to teachers' principles and beliefs that they are able to conduct the best teaching practices in the classroom (Christophersen et al., 2016).

ICT integration in education supports an influential teaching climate (Buabeng-Andoh, 2019), improves student-centered active learning (Plessis, 2016), increases student achievement (Dibaba & Babu, 2017), and enhances relevant quality education (Zheng & Chen, 2021). A previous study about self-efficacy and the employ of ICT in education verifies Bandura's premise and emphasizes the idea that improved levels of computer self-efficacy can conduct to good levels of confidence in being a competent teacher with ICT (Fanni et al., 2013). Moreover, a recent study reveals a positive link between self-efficacy in utilizing technology tools and the use of digital tools for education (Hatlevik, 2017). Above and beyond, there is a constructive relationship between teachers' use of digital tools and their digital literacy self-efficacy (So et al., 2012).

Multimedia-based instruction stems from the use of technology in education. The multimedia-based methodology helps students to work together, upsurges growth in the capital and digital world, and prepares students with active knowledge, values, and skills mandatory for the progress of the individual (Owolabi & Oginni, 2014). However, the choice of a suitable multimedia teaching tools to integrate into teaching and learning physics is extremely didactic and requires an evaluation process. Teachers' practices such as lesson preparation, teaching, and assessment methods vis-à-vis the incorporation of multimedia in physics classrooms are significant factors that contribute to the enhancement of learning from multimedia outcomes (Miller et al., 2011). Video-based multimedia is most utilized when incorporating multimedia-based methodology in teaching and learning of sciences such as physics (Adegoke, 2010; Gambari et al., 2014). Studies reported that video-based multimedia offers and encourages a learning situation where learners get involved in their individual learning, peer learning, debates, and discussion in the group about the activity to be done (Adegoke, 2010 & 2011; Akinoso, 2018). Video-based multimedia enhances competency in the application of cognitive domain and improves digital skills that are fundamental for a fruitful career in the 21st century. The justification ahead video-based multimedia in education is the usage of videos in class or out-class works where students cooperate and get involved in classroom activities, discussion, and clarification of misconceptions under teachers' guidance and facilitation. Thus video-based multimedia stems from the theory of constructivism (Bailey, 1996).

RESEARCH PROBLEM AND FOCUS

Educational literature is richly provided with research that has reported the potential of self-efficacy to predict someone's behavior. In the teaching and learning environment then, appreciating teachers' self-efficacy concerning several methodological practices is significant. However, little has been done on teachers' self-efficacy about teaching using ICTs multimedia. So, there is a need to examine factors affecting teachers 'self-efficacy about teaching physics using ICTs video-based multimedia as an instructional tool and factors that affect their current levels. Therefore, this study pursues to answer the following research questions:

What are issues affecting teachers' self-efficacy in teaching physics using ICTs video- based multimedia?

How those identified factors related to video-based multimedia in physics education could be addressed?

We have focused on self-efficacy in terms of mastery of learning experiences, personal/social persuasion, behavioral, and environmental modeling.

RESEARCH METHODOLOGY

Research Design

A qualitative research method design was used in this study. In line with the naturalist paradigm, this research employed a qualitative approach to get a complete image and in-depth information about the phenomena (Ary et al., 2020). A qualitative research design was considered suitable for this stage of data collection to obtain real information and create a visual picture of the usual situation before the implementation of the video-based multimedia intervention that was done about five weeks later.

Research Participants

Physics teachers who participated in this study were selected from eight scientific schools in Rutsiro and Rubavu districts, four schools in each district. Researchers used the purposive sampling method to select research participants. A sampling of schools was done based on digital tools and combinations that the school has. Physics teachers in senior five (grade 11) in chosen schools were invited to participate in this study. Nine physics teachers (8 males and one female) aged between 30 and 40 years old participated in this study.

Research Instruments Validation and Data Collection

The data presented in this research were collected using a set of planned and structured interviews but flexible for dialogue so that respondents can share their understandings regarding ICTs multimedia. The instruments were validated by experts in ICT education.

After selecting respondents, a one-to-one interview was planned and conducted during working time. The interview took around 50 minutes. The interview began with structured questions but the respondents were given time to share their experience with multimedia in education. The sound recorder was used to record the interviews.

DATA ANALYSIS

First, we analyzed collected data by coding; in this case, we assigned as analytically and carefully as possible to each segment recorded (such as a sentence) the semantic category to which it refers following the recommendations of Miles et al. (2014). Second, we use the constant comparison method of content analysis to classify semantic categories into developed themes and sub-themes. Then, the established themes and sub-themes were joined and synthesized through the semantic group to which they belong (Akinyode & Khan, 2018).

Ethical Considerations

Ethical matters were maintained at all stages of data collection. Ethical approval was approved by the University of Rwanda-College of Education before starting this research. Permission to collect data from the selected schools were granted by Rutsiro and Rubavu district leaders and head teachers in selected schools. All participants signed a consent form.

RESEARCH RESULTS

The objective of this study was to test the effects of teachers' self-efficacy in teaching and learning physics using ICTs video-based multimedia. This study focused on two points: issues that influenced teachers' ICT self-efficacy and the link between the recognized issues and the effective incorporation of ICTs video-based multimedia in physics. One-on-one interviews were associated with focus discussion, and later, class observation was done to collect data. Moreover, in some cases, participants' responses led to additional clarifying questions not initially included in planned interview questions.

Factors Affecting Teachers' Self-Efficacy in Teaching Using ICT Video-Based Multimedia

Coding was done on every personal interview transcript and every focus discussion transcript together with notes taken during class observation. After coding, themes and sub-themes were developed. As a result, the factors identified can be split into two main categories: intrinsic and extrinsic factors. Table 1 revealed the codes and frequency of teachers' responses.

Code	Frequency (%)
Benefits of multimedia in teaching and learning astrophysics	88.9
Teachers' access to ICT tools (computer, tablets, smartphone, Internet connectivity, etc.)	77.8
Teachers' skills in ICT tools	66.7
Teachers' confidence to use ICT in teaching and learning	66.7

Table 1: Teachers' Responses

Intrinsic Factors

The intrinsic factors that affect the teachers' self-efficacy, according to teachers who participated in this study, include the teachers' beliefs about the profits that ICT could bring to education. Factors such as teachers' access to ICT tools like computer and internet connectivity were cited by respondents as a serious problem. Respondents revealed that some teachers are technologically handicapped and teachers' fear of failure makes them feel nervous about using ICT in the classroom.

Extrinsic Factors

Teachers' insights of external support to use ICT as an instructional tool were cited by respondents as an issue that affects teachers' self-efficacy in teaching and learning physics using ICT. Those external factors include government and school support such as providing ICT tools to both teachers and students, support between and among teachers to support one another, and assistance from school administrators to promote the use of ICT in teaching. Notes taken during classroom observation revealed that teachers struggled to monitor a big size classroom with learners having different levels of ICT literacy. Time also was not friendly to both teachers and learners to accomplish their objectives.

Identified Factors and Effective Incorporation of ICT in Physics education

This section addressed how identified factors were linked to the effective incorporation of ICT in teaching and learning. This relationship was made between intrinsic and extrinsic issues that were recognized through coding of transcripts of interviews with physics teachers on the effective incorporation of ICT in teaching and learning Astrophysics. Table 2 shows teachers' views on how the identified factors could be addressed to ensure the effective incorporation of multimedia in teaching and learning.

Statement	**Frequency (%)**
Full access to ICT tools (at school and home)	100
Training on constructive incorporation of ICT in teaching and learning	100
Pair learning & sharing of experience	77.8
Administrative support	66.7

Table 2: Teachers' views to ensure effective incorporation of multimedia in teaching

Intrinsic Factors and Effective Incorporation of ICT

Teachers' beliefs, access to ICT tools, experience and ICT literacy were identified as intrinsic factors that could affect the effective incorporation of ICT in teaching and learning physics. In this regard, teachers revealed that apart from access to ICT tools (at school and home), training on the effective integration of ICT is needed. Moreover, pair learning to see the success stories of how other teachers from other schools handle the problems related to ICT in education and the benefits (to both teachers and learners) of using ICT could change positively teachers' beliefs about ICT in teaching and learning physics; hence improve the incorporation of ICTs video-based multimedia in teaching and learning physics.

Extrinsic Factors and Effective Incorporation of ICT

External issues identified that could affect effective integrations were government and school support, support from other teachers, and policy aiming at promoting ICT in teaching and learning. Respondents revealed that, to effectively incorporate ICT in education, there is a need for education stakeholders to help teachers upsurge their ICT self-efficacy in efforts to improve and increase ICT use which in turn may offer an attractive and significant learning experience for students.

DISCUSSION

The aim of this study was to examine the teachers' self-efficacy to teach physics using ICTs video- based multimedia in Rwanda. Results revealed that participants salute the effectiveness of ICT in education. Although integrating ICT in teaching and learning requires time and energy (Ghavifekr & Rosdy, 2015), teachers who participated in this study revealed that ICTs video-based multimedia should be incorporated into teaching and learning physics to support other teaching methodologies. However, some of the respondents attributed the difficulties they encountered in teaching and learning using ICT to the ICT itself.

Based on the results presented in the previous section, it has been noted that the integration of ICT in education was still admired by teachers. However, teachers have been struggling to incorporate such techniques effectively and efficiently. The previous study echoes a similar challenge that teachers faced when integrating ICT in teaching and learning that attaining digital integration is still an intricate process of educational change (Tondeur et al., 2016). Like another previous study (Guo et al., 2012), respondents in this study revealed that using ICT video-based multimedia to support teaching and learning does not depend uniquely on the availability of ICT tools. Ultimately, teachers' self-efficacy plays a crucial role in their educational choices concerning how and in what way to integrate ICT within their classroom practices. Thus, the present research revealed that ICTs video-based multimedia integration is associated with teachers' self-efficacy about using ICT video-based multimedia in teaching and learning physics in selected secondary schools' physics classrooms.

The findings of this study revealed several factors associated with the effective integration of ICT in teaching and learning physics. Although the findings of this study do not significantly differ from the previous ones, the present study suggests promising main factors for those who want to support ICT video-based multimedia integration in teaching among teachers and, consequently, the change in their teaching practices. The establishment of ICT integration strategies including teachers' professional development about ICT as an instructional tool and teachers' access to ICT tools should allow an increase in the number of teachers' sense of self-efficacy. Consequently, it leads teachers to increase the integration of ICT video-based multimedia into their teaching. Moreover, teachers should understand that ICT video-based multimedia could be an effective way of handling a big-sized class.

CONCLUSION AND IMPLICATIONS

This study aimed at examining the effects of teachers' self-efficacy in teaching physics using ICTs video-based multimedia. This study portrays novelty in understanding how and in what ways identified factors related to effective incorporation of ICT video-based multimedia will help create and integrate video-based multimedia in teaching and learning physics. One notable inference that could be of value at national and international level is that using ICT is no longer a luxury, but a necessity in the 21st century. Video-based multimedia, if properly incorporated into teaching and learning, can assist teachers in reaching objectives and offering students a chance to interact with the technological world. To do so, increasing teachers' self-efficacy is important because self- efficacy deals with someone's perceptions of his/her ability, and someone's thoughts and beliefs influence his/her actions. Moreover, when people have higher self-efficacy, they are more motivated to adopt certain behavior.

The results of this study revealed that teachers' self-efficacy is a bedrock to improve video-based multimedia use in teaching and learning. By implication, educational leaders and stakeholders should increase teachers' video-based multimedia self-efficacy which in turn increases the utilization of ICT in teaching and learning. Given that ICT has been proven to be useful in improving relevant quality teaching and learning science (Christophersen et al,. 2016) and given that teachers are the ones to implement ICT video-based multimedia as an instructional method, there is a need to provide teachers with training to effective incorporation of ICT in teaching and learning.

Further research could investigate other possible issues that can hinder the effective integration of video-based multimedia and how those factors could be addressed. Further research could also investigate the effect of other technology-based instruction tools to identify the most appropriate one for different educational settings worldwide.

Acknowledgement

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EXPERIENTIAL LEARNING IN SCHOOL MATHEMATICS: TRANSFORMING THEORY INTO PRACTICE

Tarun Tyagi

Central University of South Bihar, Gaya

taruntyagi@cusb.ac.in

Against the backdrop of a large-scale heterogeneity/diverse nature among middle school students/learners, experiential learning attracts the attention of the globe to prepare this interdisciplinary workforce that leads to ensures inclusive and equitable quality education for all. Therefore, NEP 2020 provides a comprehensive framework to foster 'experiential learning and critical thinking among students by which "Children learn to enjoy mathematics rather than fear it" (NCERT). The epistemology of this approach forms a unique perspective on learning and development because of having the interaction among Dewey's philosophical pragmatism, Lewin's social psychology, and Piaget's cognitive development. Therefore, in this research article, the pedagogical practices based on Kolb's experiential learning model are presented to achieve the learning outcomes in school mathematics. These practices may be helpful for the school teachers, prospective teachers, and curriculum planners. Educational implications and recommendations for further research are discussed.

INTRODUCTION

Learning is experience. Everything else is just information. - Albert Einstein

Despite ever-changing and increasingly complex challenges faced by the planet and humanity, there is a pressing need to educate the future generation as creative citizens to achieve the ideals of peace, freedom, and social justice that leads to the welfare of human beings globally. For this, mathematics provides a suitable platform. It plays a pivotal role in the everyday life of human beings as well as an important place in the school curriculum. It opens the door for the prosperity of any nation and helps in providing solutions to the problems posed in social, cultural, and natural environments. National Education Policy (NEP 2020) highlighted that Mathematics and mathematical thinking are very important in the numerous upcoming fields and professions which involve artificial intelligence, machine learning, data science, etc. National Council of Teachers of Mathematics (NCTM, 2000) highlights that all students deserve to learn Mathematics (NCTM, 2000) and have an equal right to quality mathematics education. In support, the National Focus Group on Teaching Mathematics (NFGTM, 2005) advocates that all students can learn mathematics and that all students need to learn mathematics. In this changing world, those who understand and can-do mathematics will have significantly enhanced opportunities and options for shaping their futures (NCTM, 2000). The vision of school mathematics, "children learn to enjoy mathematics rather than fear it" is simple in words but grand in execution (NCERT). Therefore, to achieve the target to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all, The National Education Policy (NEP) 2020 provides a comprehensive framework to foster 'experiential learning and critical thinking among students in the field of mathematics, science, and language, etc.

Against the backdrop of a large-scale heterogeneity/diverse nature among future learners, the educational professional must explore how innovative teaching methods/strategies help the future learners learn to live together in the 'global village'. In which experiential learning attracts the attention of the globe to prepare this interdisciplinary workforce that leads to recognize and tackle ethical, cultural, political, and equity issues for a sustainable and just future (Hong & Page, 2004; Yarime et al., 2012). Despite efforts for inclusive and equitable education for all, the number of students nationally as well as globally (worldwide) are struggling from their unsatisfactory performance in mathematics learning (NAS, 2017; ASER, 2018; OECD, 2016). Therefore, in this situation, scholarly attention is required to explore the mathematics concepts and make students motivated to learn.

THEORETICAL FRAMEWORK

Experiential Learning

Several educationists worldwide have advocated an experiential learning approach that promotes teachers and students acting as observers and each of them interpreting according to their own learning style. But the practice of experiential learning approach is mentioned in the Taittiria Upanishad (Gambhirananda, 1989). The idea that a hermeneutic endeavour can be structured as a normative primary task can be traced to these experiential learning traditions where Gurukul is the quintessential experiential learning place of 'Simple Living and High Thinking' initiated by an interaction between the learner and his environment for stopping rote learning or instruction. It focussed majorly on 'inner experience' – living experience from inside to unfold the metaphysical truths of nature. The whole Vedic culture continuously emphasized that philosophy must be based on experience; not the empirical experience of the senses but the inner mystical experience or the third eye of knowledge. Ergo, self-experience was considered the main source of true learning. The concept of anu-bhava (the Sanskrit word for a unit of experience) contains the ideas the minuscule impressions constitute emotional, aesthetic, and psychological crystallization of experiences.

Experiential learning is built upon the foundations of interdisciplinary and constructivist learning approaches. The experiential methodology doesn't treat each subject as compartmentalized within its walls. It seeks to create an interdisciplinary learning experience. At the same time, it focuses on the constructivist theory of learning which recognizes and values differences in learning aptitude among learners. Learning is done by students constructing knowledge out of their experiences. It moves beyond the myopic 'one size fits all' teaching formula. Experiential learning, in the digital world, is a blended form of learning which essentially has rich content including field trips, DIY experiments, and much more. Vedic education comprised three processes:

1. Sravana- Listen and understand
2. Manana- Reflect
3. Nididhyaana- Complete comprehension by realization and experience
4. Samadhi/Sakshatkar

The experiential learning theory by Kolb is based on Dewey's philosophical pragmatism, Lewin's social psychology, and Piaget's cognitive developmental genetic epistemology. John Dewey was one of the earliest educators who proposed experiential learning. "Give the pupils something to do, not something to learn; and the doing is of such a nature as to demand thinking; learning naturally results" (Dewey, 1916). Yet not all experience is good. It is important at the outset to confront this important truth head-on. Even John Dewey (1938), the high priest of experiential learning said that-

> The belief that all genuine education comes about through experience dons not mean that all experiences are genuinely educative. (Hopkins & Putnam, 2013)

Experiential Learning (EL) is defined as an approach where learners are brought directly in contact with realities being studied. EL theory is a "dynamic, holistic theory of the process of learning from experience and a multi-dimensional model of adult development (Kolb, & Kolb, 2017). As proposed by Kolb and Kolb (2005), the EL model builds on two learning processes:

1. How students approach new experiences and abstract conceptualizations.
2. How these experiences are in turn transformed into new learning-that is reflective observation and active experimentation.

According to Kolb's model (1984), experiential learning is a four-step process: Concrete Experience (CE), Reflective Observation (RO), Abstract Conceptualization (AC), and Active Experimentation (AE) which is given below:

1. Concrete experience: Active involvement in the discrete task which is potentially disruptive regarding student's beliefs and ideas
2. Reflective observation- The process of resolution of the conflict between differences which makes students move back and forth between hypotheses and values
3. Abstract conceptualization- Making sense of what has come of the experience and the reflection, by creating, mixing, or building on models and ideas
4. Active experimentation- Putting into action what they have learned, placing it in a context that is relevant to the students. It is shown in the given figure (source: NCERT Book)

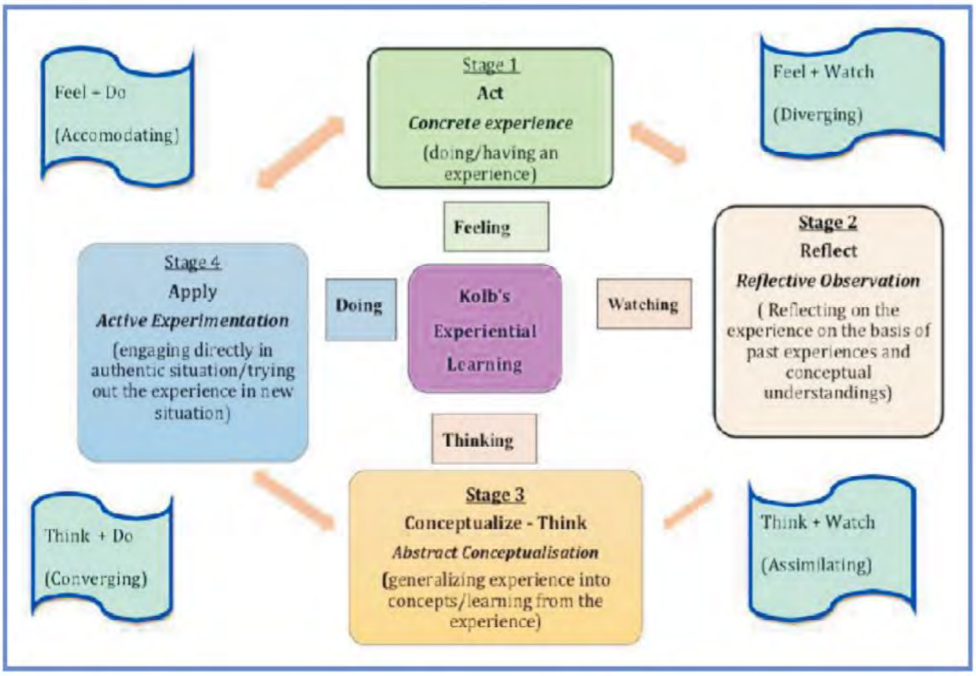


Figure 1 Framework of Experiential Learning

Experiential learning is a holistic philosophy of education based on the notion that an individual's life experiences, education, and work play a central role in their learning and understanding of new knowledge. The role of the teacher in this process is to facilitate rather than direct the student's progress (Kolb & Kolb, 2009). It is not a set of tools and techniques, in turn, it can be used as a method of instruction to support a personalized approach to learning in a higher education context that often values the student undertaking learning in a variety of campus-based, project-based, work-integrated, and community contexts.

Significance of EL in T-L Process

According to UC-Davis (2011), EL provides opportunities for students to involve in practical, social, and personal problems; freedom in the classroom, and involvement in challenging situations while discovering and self-evaluating their progression or success in the learning process which becomes the primary means of assessment. According to Wurdinger and Carlson (2010), the roles of educators in Experiential Learning are as follows: (i) identify experiences that students will have a personal connection to and interest in. (ii) tie the course learning objectives to course activities and direct experiences so that students know what they are supposed to do; and (iii) allow students to experiment and discover solutions on their own.

PURPOSE OF THE STUDY

The teaching profession requires the true professional for preparing the future teachers to perform well from a national and international perspective. Learning is not simply about the acquisition of knowledge and skills it is an embodied experience in which the learner acts within an environment and comes to make sense of this experience through a reflective process (---). The experiential learning approach attracts the attention of professionals of the teaching profession. However, numerous studies have been conducted in this direction especially in the subject of science, math, commerce than in social sciences. It is demonstrated by the different research studies that experiential learning positively affects the students' learning outcomes (Agsalog, 2019; Bradberry & Maio, 2018) in Chemistry (Thote & Gowri, 2021), mathematical creativity (Chesimet, Githua, & Ng'eno, 2016); cognitive and social skills (Voukelatou, 2019), Biology (Nwuba & Osuafor, 2021), social studies (Speicher, 2017) and increase the motivation (Adams, 2018), and engagement and interest (Woods & Teresa, 2011).

After analysis of the above-mentioned research findings, the researcher realized that ample evidence of the research studies in the field of experiential learning approach has been found overseas but not nationally as reviewed by the author. Despite fetching the attraction by NEP (2020), the scholarly attention towards the use of ELA in the teaching-learning process is sparse yet. Therefore, in view of the above discussion on the basis of studies reviewed and finding out the research gap, therefore, in this research article, pedagogical practices based on ELA have been presented for achieving the learning outcomes in mathematics at the upper primary level.

HOW CAN EXPERIENTIAL LEARNING BE USED?

Experiential Learning Lesson Plan- Mathematics

Class-VIII

Topic- Square Roots

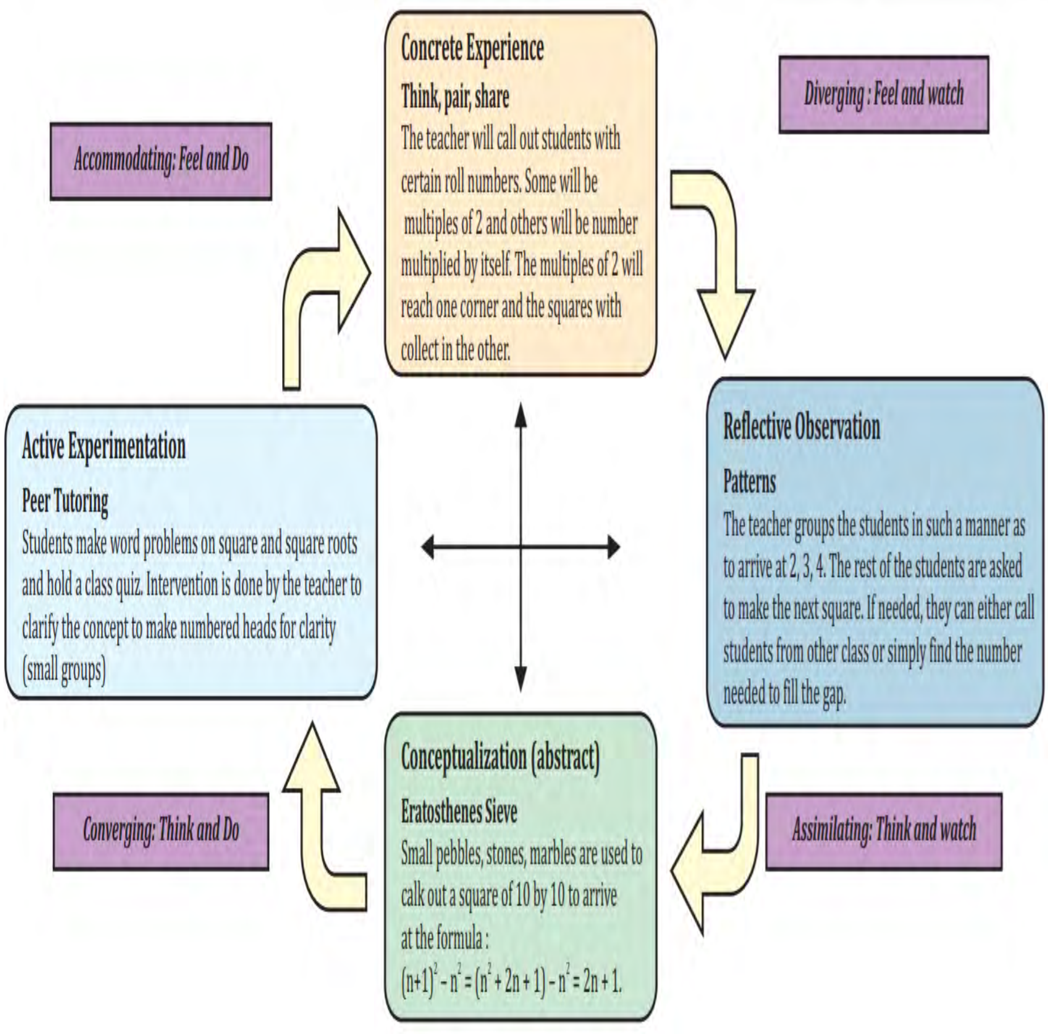


Figure 2 Source NCERT Book

USE OF EXPERIENTIAL LEARNING APPROACH IN MATHEMATICS

Preliminary Information/Planning Phase:

The following points are decided from the beginning of transacting the content.

1. School: High School, Tepa Fatehpur, Gaya (Rural)
2. Class: VII
3. Subject/Area: Mathematics (Geometry/Mensuration)
4. Content: Area & Circumference of Circle
5. Justification: This activity will be helpful for gaining basic knowledge and skills about the role and functions of circular objects and the importance of circular objects in human life. Further, how mathematical operations are performed to find out the area and circumference of the circular objects.
6. Objectives/ Learning Outcomes: Students will be able to:

   a. to define the terms related to circular objects like radius, diameter, and circumference.
   b. to explain the circumference of a circle.
   c. to explain the causal relationship between the circumference of a circle and its diameter.
   d. to find out the area of circular objects.
   e. to appreciate the importance of the circle and circular objects in our life.

7. Pedagogical Practices: Think-pair-share, group discussion, fieldwork, and group activity
8. Approach:Activity-based approach
9. Teaching Learning Materials: Cardboard, Circular Objects, Ball, Bangle, Compass, Scale Scissor and Bundle of String, etc.)
10. Time Plan:
    a. Preparatory class- 15 minutes
    b. Time for activity-30 Minutes
    c. Feedback/ Evaluation of Learning Experience: 15 minutes
11. Planning for Visit the Site:
    a. Invite the total number of the students (max 40)
    b. Create five groups in heterogeneous nature consisting of 8 students in each group
    c. Select the leader for each heterogenous group
    d. Ensure the required material in all groups collaboratively
    e. Select the open place for sitting all groups in a circular form
12. Role of Teacher:

Setting the Stage for Learning

Testing the Previous Knowledge: What do learners already know?

In sub-groups, Teacher (T) may use the different devices to test the previous knowledge of the student (S)-

1. T- Ask students one by one about some real-life objects that they have in and beyond the classroom?

   S- One by one student list the name of the objects as they have in and beyond the classroom.

2. T- After receiving the responses from the students, mention them on the blackboard and categorize them also. But not mentioned the criteria of classification and even ask the students to explore the reason behind this.

   S- Think

3. T-List out some real-life objects as mentioned on the blackboard in which is made with the use of line segment?

   S-the edge of a greetings card, box, table, pencil, ruler, finger, legs, etc.

4. T-Similarly, list out some objects in which parallel lines are used.

   S-Railway line, scale, window, blackboard, notebook lines, etc.

5. T-What types of real objects in your surroundings that is prepared a part of the line that has one endpoint and goes on infinitely in only one direction?

   Ss- Torch, Sun Rays, the light of Vehicle, etc.

6. T- Dear Students, what types of real objects in daily life are not made by straight-line only?

   Ss- No

7. T-Is it possible, some objects can be prepared without straight line means with the use of curved lines?

   Ss-Yes

Implementation of Lesson Plan - Stage 1 Preliminary phase

Sparking curiosity: Introductory phase to create interest and stimulate learners' curiosity.

In sub-groups, ask children to-

1. T-Take a piece of paper and just doodled/Scribbled it? Dear Students, what types of images/figures are you observing in the doodled paper? Now see the different images/figures /pictures as you can see from a different lens?

   S- Different figures like open & closed figures, triangles, polygons, etc.

2. T-Think about your body parts and find out the body parts where straight lines and curved lines are used?

   S- Straight lines-Fingers, hands, legs, etc, and curved lines- the front part of fingers, ears, eyes, head, nose, shoulders, etc.

3. T- By using straight lines the different kinds of polygons can be created/prepared. What are those?

   S- Rectangle, Square, Triangle, etc.

4. T- Similarity with the use of curved lines or arcs, which/what types of figures can you create?

   S- Expected responses like a circle, round shape, circular, etc.

Providing the theoretical information before experience: Different models and objects in the circular form related to observable in students surrounding and real-life are shown to the students for their experiences and feeling.

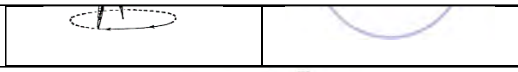
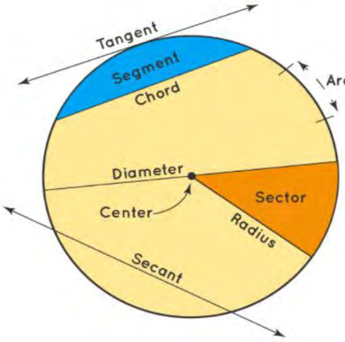
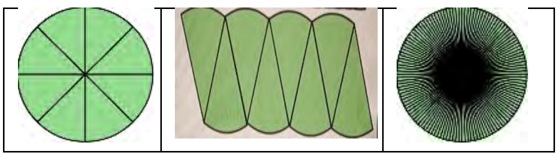
Figure 3

T- A circle is a path of a point moving at the same distance from a fixed point. The fixed point is the center, the fixed distance from the path to the center is called a radius and the distance around the circle is the circumference.

Concrete Experiences: Providing the concrete experiences by using experiential learning approach.

After discussing the circular objects in each group, the students are asked to identify the different dimensions; size, shapes, etc are noted and discussed by the students in the classrooms.

Figure 4

<table>
<tr><td>All Groups</td><td>Observations</td><td>Activities</td></tr>
<tr><td>Activity-1</td><td>To draw a circle with a compass
To draw a circle with a string</td><td></td></tr>
<tr><td>Activity-2</td><td>To identity the components like
(1) Centre
(2) Radius
(3) Diameter
(4) Arc
(5) Chord
(6) Tangent
(7) Secant
(8) Sector</td><td>
</td></tr>
<tr><td>Activity-3</td><td>Circumference
(i) Draw 3 circles at least with different radius and find their circumferences by using string & scale
(ii) Thereafter find the ratio of the circumference to the diameter</td><td><table>
<tr><td>Circle</td><td>R (cm)</td><td>D (cm)</td><td>C (cm)</td><td>Ratio (C/D)</td></tr>
<tr><td>1</td><td>3.5</td><td>7.0</td><td>22.0</td><td>22/7=3.14</td></tr>
<tr><td>2</td><td>7.0</td><td>14.0</td><td>44.0</td><td>44/14=3.14</td></tr>
<tr><td>3</td><td>5.0</td><td>10.0</td><td>32.0</td><td>31.4/10=3.14</td></tr>
</table>After observing the pattern between the relationship between C and D, it is inferred that
C/D= 22/7 or 3.14
C/D= pi
$C = \pi D$ [D =2r]
Therefore, $C = 2\pi r$</td></tr>
<tr><td>Activity-4</td><td>Area
(i) Find out the area of a circle
Observations:
- made the circle with unlimited small sectors
- a group of small sectors converts into a rectangular form</td><td>Find out the area of circle = πr^2
</td></tr>
</table>

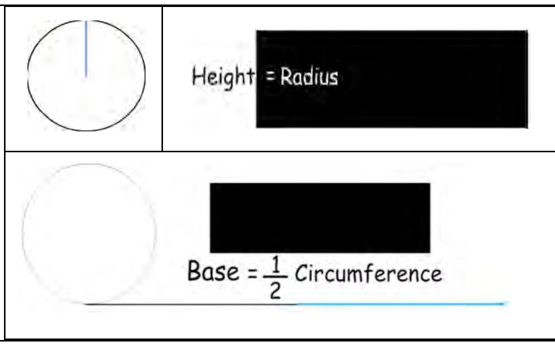
	- Therefore, the area of a circle is equal to the area of a rectangular figure whose height is radius and base is half of the circumference So, Area = Base * Height = ½ Circumference * Radius = ½ *2 πr*r Area of circle = πr^2	

Table 1

Reflective Observations: Drawing inferences based on experiential learning according to their potential use of past experience and conceptual understanding

First Step: A pin is fixed on a cardboard/wood board and string is tied to it with chalk/pencil/marker. After directing the teacher, every group will draw different circles on a cardboard/wood board by increasing or decreasing the length of the string. Besides this, students may try to form circles (ethnomathematics) using a stone and a rope as shown in the figure (in the field) and find out the different ways to draw a circle.

Second Step: Students in groups are given different ropes and they are asked to form circles with the help of those ropes. Then they increase and decrease the size of the circles formed by adding or reducing the members in each group.

Third Step: The teacher presents the following questions. Observations of figures from a different lens during experiments, and the students respond to those questions by think pair-share techniques:

1. Requirement of things/material to form a circle
2. Effect of increasing and decreasing the number of students and the length of the rope to draw/make a circle
3. The length of the string concerning different points in the different circles
4. Length of different line segments/chords formed in the circle
5. Relationship between the line segment and the length of the string

Lesson steps: Conclusive phase

Abstract Conceptualization: Assimilate key aspects of learning from the inferences drawn by learners.

Based on the information, the conclusion will then take the shape of understanding that different types of banks and their functions and bank is an important part of our society in order to cater to our need and best partner of the Govt. for economic development.

First Step: Students infer the concepts of circles like center, radius, diameter, and circumference by answering the questions mentioned in PHASE II. They arrived at a conclusion that

1. One center point from which the circumference is equidistant from the center point of a circle.
2. Relationship between radius and diameter in the circle.

3. The distance around the circle is called its circumference.
4. Circumference of a circle is always more than three times (approx.) its diameter
5. Relationship among chord, segments, centre, and circumference.
6. A chord of a circle is a line segment joining any two points on the circle.
7. The process for exploring the area and circumference of a circle.

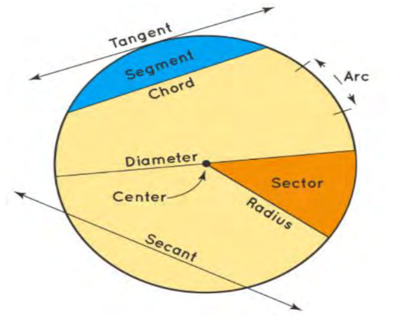


Figure 5: Circle and Its components

Students experience the learned concepts in other situations and use of circular objects in real life. Circular objects are around of us, like; wheel of a bicycle, the wheel of bullock-carts, clocks, coins, buttons, dishes, fans, ornaments (Bangles, etc), compact disc, giant/Ferris wheel, etc.

Active Experimentation: To extend the lesson for linking/connecting with real-life situations

Students work in groups (8 students in a group) to do the task-

1. draw circles of different sizes in their notebooks (with the help of a pencil, scissors, glue, cardboard, a geometry compass, and string)
2. Find the different measures/components that formed a circle
3. Find the circumference of a circle
4. Find the area of a circle
5. Explore the process to convert the circular figure into the same area of different geometrical shapes like rectangle, square, and triangle

In the following figure you are asked to observe the situation and accordingly think and connect the things/ideas from your real-life activities and explore the process to find out the radius, diameter, and circumference of the circular object.

Figure 6

Assessment: Students will be asked to provide the solutions to the given problems-

1. In the following figure, A boy runs around a rectangular park, with a length of 50 m and breadth of 38m whereas a girl runs around a square park on a side of 44 m. Who covers lesser distance?

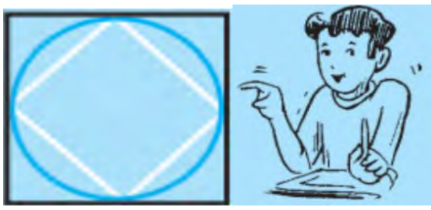


Figure 7

2. A cow is grazing in the two fields of a farmer in which one field is circular and the second is a square type. However, both fields have the same perimeter. The cow has grazed the maximum area of which one type of field. Think about it.

Their responses in the journal will be derived through their understanding of the lesson and analysis of their needs and socio-economic status. Their responses in the journal will be derived through their understanding of the lesson and analysis of their needs and socio-economic status.

Teacher's Learning (Post-Lesson Reflection): What challenges /problems does the facilitator face while planning and implementing the lesson plan?

CONCLUSION & DISCUSSION

The experiential learning approach emphasizes the importance of learners' self-experiences with the connection of their surroundings or real-life setting problems. This paper suggests the pedagogical practices in mathematics with the use of real-world problems for developing the interest, motivation to learn, and for achieving the learning outcomes effectively. No need for instructional focus on speed and right response while students are learning at their own pace but motivated to share the ideas in the classroom for stimulating the other students' thinking and enhancing participation in the classrooms. By using an experiential learning approach teacher can help the students for using the previous and new knowledge for refining a network of knowledge and prepare them for further social science learning. During the process of developing the situation, the authors found many similarities between the steps of Kolb's experiential learning model and the different activities, PBL, etc for teaching concepts. Ergo, longitudinal, cross-lagged panel study (Tyagi & Singh, 2014) and experimental research may conduct in this direction by which support systems can be provided for them.

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EXPLORING THE SCOPE FOR USING DATA SCIENCE IN THE TEACHING AND LEARNING OF MATHEMATICS: AN ACTION RESEARCH AMONG SECONDARY SCHOOL STUDENTS

Jasneet Kaur

SCERT, Gurugram, Haryana, India.

she/her/hers

kaurjasniit@gmail.com

This is an action research-based study that explores the scope for incorporating data Science in the teaching of mathematics. The problem was identified using the design thinking process during Covid-19 about how to engage and arouse curiosity among secondary school students and connect with mathematics which was meaningful to the students at the time of Pandemic while attending online as well as offline modes of teaching. The study was initially conducted on grade 9 students online both synchronous and asynchronous mode as well through offline mode and then extended to 8th and 10th graders too through online mode (Synchronous). A data visual related to handwashing was presented to students and students were asked to work upon it. The study reveals that though the students had the first time saw such kind of task in their teaching-learning process, the task made them excited and explorer. Few students could come up with the mathematical connections trivially while exploring the task. The task also proved to be a group worthy as well as had the power to initiate discussion.

INTRODUCTION: DATA SCIENCE AND MATHEMATICS

We are at an exciting time, both in terms of the knowledge that is available in the world and the ways the knowledge is being made available, it is called the time of the Data revolution. The studies (Messy Data Coalition, 2020; Tanya La Mar and Jo Boaler, 2021) highlight the importance of data and reveal that our lives and our students' lives are filled with data. All around the world, decisions are being made about our lives, using data. The kinds of advertisements that pop up on our smartphone or computer screens; medical procedures that are used, all are data decisions. Some studies (Zucker, Noyce, & McCullough, 2020; Erickson et al., 2019) also point out that failing to note the patterns or the bigger picture of the data or not being able to assess the quality and validity of the data could be a threat to the democracy itself, so it seems that a data literate citizen is now an important part of living in the world. Research has also shown that when maths is engaging for students, they are given opportunities to make connections between ideas and topics they learn (Boaler, 2002, 2015; Boaler & Staples, 2008); and when they are given real-world problems and work with others (Boaler, Cordero & Dieckmann, 2019), deep understandings are gained specifically to marginalised students. Therefore, it is emphasized that data Science should become the new pathway in school mathematics and students needs to be comfortable with data, looking for patterns in data, communicating important insights from data. Questioning, pattern-seeking, working as a detective, taking mathematical meaning out of the data and communicating one’s findings are important features that connect it with mathematics.

THE PRESENT STUDY

The objective of the study was to engage and arouse curiosity among secondary school students and to make maths meaningful to the students at the time of Pandemic while attending online as well as offline modes of teaching. The study employed the design thinking process which usually consists of 5 steps – viz (i) Empathizing (ii) Defining the Problem (iii) Ideate (iv) Prototype (v) Experiment/ test and iterate.

Empathizing is considered as a foundation to the human-centred designs and it is therefore considered important to observe, engage and immerse with the users. Empathy map actually guided to dive into the problems students facing in their teaching and learning and then prioritizing the problems. It was followed by ideating and brainstorming to find a solution to the problem and then creating a prototype before testing and experimenting Quotes shorter than two lines are normally included within the text, inside quotation marks. For longer quotations, use the following style.

Setting the context

The study was conducted on around 60 girls students of a Government school located in the semi-urban settings Faridabad situated in the National Capital Region (NCR) bordering of Indian Capital New Delhi. The school caters to the girl students of labourers, migrants and workers in small scale industries comings from within a 3-4 km radius of the school. Almost 50% of the students belong to the reserved category and 90% of the students are first-generation learners. Most of the students lived in small rented houses with single room accommodation in a meagre community area. Most of the girls remain involved in helping domestic work and taking care of the siblings as both parents' work.

During Pandemic session 2020-2021, It took 2-3 months after March month to work through online teaching mode due to unavailability of smartphones (can't even think of computer or laptop), no money to top up internet connections and moved to their native places(villages). The situation was a little better with the board class students (X graders), almost 70% of the students had availability of smartphones. However, there were other challenges like topping up data plans on time due to lack of money, unstable data connection, poor quality of the mobile phone, health problems (having stone, low on HB are the most common, severe headache (they say-upery saaya) still prevails due to which there was an increase in absenteeism and irregularity in daily Teaching and learning. Moreover, almost 50% of the students had their smartphones available late in the night or early in the morning as their parents or siblings took the phone at workplaces. The situation was very different with IX graders as almost 50 % of the students had smartphone availability and almost 90% of this cant access their phone during the daytime as it is with their working parent or sibling. As far as their learning space at home is concerned, few students might have separate or conducive spaces to study. The rest of the students shared their space with their siblings. The students have connected with me through whats app group apart from some online classes. Apart from this, students were also allowed to come for their doubt clearing sessions on the basis of rotation. While empathizing, engaging students and making maths meaningful full was the problem which was workable and was on highest priority. After finalizing the problem and with much ideating and researching, it was decided that students would be presented with a handwashing data visual for the data talks.

Data resource

Hand washing data visual was adopted from the resources available under creative commons license from the theYoucubed.org website with the following link.

https://www.youcubed.org/wp-content/uploads/2020/09/HandWashing.pdf

The handwashing data visual presents the data from a study that evaluated the handwashing techniques of health care professionals in 1978. The visual represents the most often missed area, often missed area and less often missed area after washing the hands. Students were asked to observe the visual and then answer two questions- (i)What do they notice? (ii) What do they wonder about?

Experimenting (the tryout)

The first part of the design solution was tried out with IX and X class students. It was about showing a handwashing data visual with the vision to improve upon their engagement in maths learning by fostering the aspect of curiosity and visualization. Students were expected to do data talks and explore the aspects in the visual that they wonder about.

Testing was done using three modes: (i) Zoom platform, (ii) In person, (iii) Using whats app. In zoom platform, Testing was done on a group of six students of 8th class and it was observed that they were able to notice different aspects of the data visual but was a bit confused in the terminology used to indicate certain areas in the data visual given to them. More interactions were observed when the data visual was presented to 9th grade students in the offline mode. Using WhatsApp, out of five students only three responded two in the form of writing and one in the form of audio. Later on, the task was done with all the students from VIII to X graders taking an online class.

FINDINGS AND DISCUSSION

This section would discuss some of the categories that emerged out of the data.

What did they notice?

Students could make out that the hand visual represents only one hand and what does red, orange, yellow and white colors represent. However, there was confusion that whether the missing area means the area with more germs or it is the area that is not cleaned or it is the area that is not washed while hand washing. Most of the students meant areas with germs as the most often missed area.

https://flowingdata.com/2020/02/18/most-often-missed-areas-while-washing-hands/

What do they wonder?

The most wondering aspect was how is it feasible that after washing hands there is so much area left for cleaning.

Data Seeks Data

One of the interesting findings was that data visual arouse many questions among the learners and made them think to validate the visual through different strategies to collect more data. Some of the novel questions like how this data had been collected; what was the need to collect

this data was raised. While students were observing the visual and discussing, researcher spontaneously asked a question that whether they consider this data as real or fake. Few students consider the data as not real as they were not believing that after washing hands how there is so much missing area left. Further, during online mode, a girl who never responded in the class (for almost 3 months) suddenly unmuted and said that she thinks that data visualization is real and she has just washed hands in the way she usually does and also observed carefully. She could notice that the parts which are shown in the visual as missing were actually missed while she was washing her hands. Further, while discussing the visual with 10th graders, many students wanted to collect data from their family members on how do they wash hands and then validate the existing visuals.

Data seeks collaboration

The importance to discuss with somebody and the importance of what others were thinking was felt while data visual was presented to the students in person. While students were raising questions like how this data had been collected, they actually felt the support of other peers to express their thought too. Further, there was confusion created among students related to the categories made on the data visualization that led to the intense discussion among students.

S1: there are so many germs in the hands. (Translated)

S2: it is written most often missed area, not that there are so many germs (Translated)

S1: so, what is the difference, if it is not washed means there are many germs. (Translated)

S3: It is not necessary, if we do not use the upper portion of our thumb for any work, how would germs come. (Translated)

S4: from the air. (Translated)

S5: I am wondering, how can some part of my hand be missed from washing if I am washing my whole hand.

Did data talk lead to maths talk?

It was observed that students begin to talked about the missing area informally, e.g. ‘missing area is too much’. This became the entry point to connect with mathematics as researcher asked ‘How Much?’. At the initial level, most of the students started with estimation. Some of the common responses were-

‘¼th of the area is cleaned in the hand’.

‘60% of the area is cleaned’.

‘80% of the area is dirty’.

‘In the palm more than half but less than ¼ is cleaned but on the opposite side less than 1/4th is cleaned’.

While discussing and getting deep into the data, when students were asked how would they validate whether their estimations are genuine or not. Surprisingly, many students suggested to decompose the hand visual into rectangular shapes and then using the formula(l*b) to find the area. The reason for such kind of response was obvious as, in their previous classes, they have studied concept of area with respect to the polygons mainly the formulae to find the areas of rectangles, squares and triangles. To find out the area of an irregular figure was a new task for them. There were Few students suggested that she would divide each part of hand equally to find the area. For example, dividing the little finger equally into four parts and then the middle finger and so on. Few students suggested that they would divide the hand visual in equal squares and would calculate the area of each category. Further, another student wanted to trace the visual and draw it on graph paper directly to calculate the area by taking counting the squares. Moreover, it is also interested to note that students never encountered with the irregular figures while learning fractions (usual approach is area model using circles or rectangles), during discussion, they started making connections between area, percentage and fractions. As initially, they started estimating the area in terms of percentages and while calculating the area, they used part and whole relationship, the student who drew the visual on the graph, roughly added all the squares -36 and most often missed area (red colour) – 6 squares. During discussions, students revealed that 6 out of 36 means 1/6th of the area and later on one students said 1/5th would mean 20% so most often missed area would be less than 20%.

CONCLUSION

It can be concluded from the study that though data visual managed to arouse curiosity and engagement among students, it could not work much with whats app teaching. The reason might be that students were first time seeing the data visual. Further, the data talks on the data visual were providing students to make connections among different maths concepts in a natural way as the data visual was very much connected with their present context.

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FLUENCY IN SINGLE-DIGIT ADDITION AND RELATED SUBTRACTION FACTS AMONG INDIAN STUDENTS

Praveena Katragadda[1a] and Maulik Shah[2b]

Educational Initiatives, Bengaluru, India

[1]she/her/hers, [2]he/him/his

[a]Praveena.k@ei-india.com, [b]maulik.shah@ei-india.com

Proficiency in basic arithmetic facts impacts overall math ability and higher mathematical competencies. The study describes one of the means to measure fluency in single-digit addition and related subtraction facts, and reports levels of fluency in 550-600 students of grades 3, 4 and 5 each in 44 government schools in Rajasthan and Himachal Pradesh, and 4 private schools in Ahmedabad at the start of their academic year. A gap between levels of fluency in single-digit addition facts and related subtraction facts was found among students. A considerable difference in levels of fluency among students in private schools and government schools was found. The private school students above 75th percentile in grade 3, above 50th percentile in grade 4 and above 25th percentile in grade 5 were fluent with addition facts. In government schools, even the students above 90th percentile were not fluent in both addition and subtraction facts in grades 3, 4 and 5 (except grade 5 in addition facts). A few strategies often self-invented found among students in few other English-medium private schools are described. A student typically used any of the mental strategies, counting on figures or using marks on paper to count and answer for different facts. Students tend to count on fingers more for subtraction facts than addition facts. Based on the findings we propose educators should focus on developing fact fluency especially among government school students and include measuring fluency in formative assessments.

Keywords: fact fluency; addition facts; subtraction facts; government schools

INTRODUCTION

The ability to read and write, and to perform basic operations with numbers, is a necessary foundation and indispensable prerequisite for all future school and lifelong learning (The National Education policy, 2020). One of the main objectives of the NEP, 2020 is to achieve universal foundational numeracy by grade 3 by 2025.

Most children use primitive counting strategies in the early years when working with basic arithmetic. Characteristic for good development is when children evolve their arithmetical skills through more advanced counting strategies, and furthermore when they retrieve basic arithmetical units (e.g. 2 + 3 = 5) without any need for counting support in their calculations (Carpenter & Moser, 1984; Siegler & Shrager, 1984; Ostad, 1999). Addition and subtraction facts fluency is the ability to compute a single-digit addition fact or the related subtraction fact in 3 seconds or less (Jordan & Montani, 1997). This can be achieved either by retrieving the fact from memory or by applying efficient strategies like doubling, decomposing the given fact to a known easier fact, by converting the subtraction fact to a known addition fact, etc. The retrieval deficit of arithmetical basic facts can be said to be a useful indicator in the diagnosis of learning difficulties in mathematics (Ostad, 2000; Geary, 2004). In Adding It Up: Helping Children Learn Mathematics (Swafford, J., & Findell, B. (2001), the National Research Council

(NRC) concluded that attaining computational fluency—the efficient, appropriate, and flexible application of single-digit and multi-digit calculation skills—is an essential aspect of mathematical proficiency. The fluency in single-digit addition facts (and related subtraction facts) would allow a learner to focus on steps of a multi-digit addition (and subtraction) and ease cognitive load. Cummings and Elkins (1999) showed that students solving facts more fluently and students using more sophisticated strategies to answer facts make fewer errors in multi-digit computations.

Students who have **not** achieved addition fact fluency may still be in one of the earlier stages described here. (1) **Count all strategy (counting strategies):** First they solve addition facts using count all strategy using counters, by drawing lines circles or any such figures, counting using fingers. e.g. While solving 2 + 5 using fingers; the student counts 2 fingers first, then 5 other fingers. He then counts all the figures to count them totally as 7. (2) **Count on strategy (counting strategies):** Instead of counting both the addends (count all), now students will start counting from either the first addend or the larger addend. E.g. Count on from the first addend: While solving 2 + 6 the student counts to 8 starting from the first addend, 2 and count as 3, 4,...8 in the initial phase. Count on from the larger addend: Students count 2 + 6 as 8 starting from the larger addend, 6 and count as 7, 8 in the later phase. The counting can be by using counters, fingers or verbally. (3) **Composition or decomposition (reasoning strategies):** In the next stage, they start applying other efficient strategies (often student invented) like decomposing the sum to a known simple fact (8+5 as 8+2+3 or 5+5+3), or a fact with one of the addends as 10 (9+8 as 10+8 -1 or 9+1+7), doubling (6+6 as 2×6), near double (9+8 as 2×8 + 1) etc. (4) Then students may start retrieving facts from memory and we say they have developed automaticity. Students may first develop automaticity with simple addition facts in which each number is less than 5. They then typically attain fluency with sums up to 10 and eventually all pairs of single-digit numbers.

The study seeks to answer the following research questions. a) What are the measures to measure the levels of fluency in single-digit addition facts and related subtraction facts? b) What are the levels of fluency in single-digit addition facts and related subtraction facts? By what grades students develop automaticity? c) Are there significant differences in the levels of fluency among government schools and high-fee English-medium private schools?

METHOD

Participants

Around 560 students from each of the grades 3, 4 and 5 of 22 government schools in Solan district, Himachal Pradesh, 22 government schools in Udaipur district, Rajasthan (the medium of instruction is Hindi in all these schools in both the states) and around 60 students per grade from 4 high-fee private schools of Ahmedabad, Gujarat (the medium of instruction is English) participated in the study. For the assessment, students were selected at random from the class (first 10 odd-numbered or even-numbered students as per their roll calls). The assessments were administered at the beginning of the academic year (around 1 - 3 months after the start of the academic year).

Measures

The measurement of fluency levels in single-digit addition facts and related subtraction facts was part of a larger study comprised of measuring different aspects of foundational numeracy among participants. The measures (assessments) including the ones to measure fluency in single-digit addition facts and related subtraction facts were developed by adapting the Early Grade Mathematics Assessments (EGMA) toolkit which was designed and implemented by the Research Triangle International (RTI) and United States Agency for International Development (USAID) (RTI International, 2014). The measure for addition-facts comprised of 20 addition facts of single-digit numbers with sum up to 5, 10 and 18 in increasing order of difficulty by large. It included facts which add up to 5 (e.g. 2 + 3 = ___) and 10 (7 + 3 = ___), facts like 8 + 8 = __ etc. The measure for subtraction facts had 20 subtraction facts related to the addition facts (e.g. 5 - 3 = ___, 16 - 8 = ___). Students were expected to tell the answer of as many facts as they could, orally, in 2 minutes. They solved the facts in the given order. They could skip if they don't know the answer to such a fact. Students were allowed to work out the solution on a piece of paper if they wanted to.

The EGMA recommends 1-minute timed tests to test the addition and subtraction fluency whereas we had given 2-minutes for the student to answer as many addition or subtraction facts as possible of different types. This was done to ensure more facts and variety of them are answered to measure levels of fluency more accurately. Our pilot study revealed more students in government schools answered only a few basic facts in 1 minute while answering them in order and the measure had facts in the increasing order of difficulty by large. The levels of fluency are reported as the number of facts answered correctly (number corrects) per minute. The measures are the same for all grades 3, 4 and 5.

The assessments were conducted in a one-to-one interview by trained field evaluators. A two-day evaluator training was conducted by the research team a week before the test conduction.

RESULTS

The average number of facts answered correctly per minute by government and private schools are shown in table 1.

Grades	Addition fact fluency		Subtraction fact fluency	
	Government school students	Private school students	Government school students	Private school students
Grade 3	6.6	17.4	4.0	14.3
Grade 4	10.0	24.4	6.5	21.1
Grade 5	11.6	29.2	7.8	24.4

Table 1: Learning levels on addition and subtraction fact fluency: Average number of facts answered correctly in a minute (ncpm)

	Grade 3		Grade 4		Grade 5	
Percentile	Govt.	Pvt.	Govt.	Pvt.	Govt.	Pvt.

10th	0	9.2	3.5	13.4	5.5	13.6
25th	2.5	11.5	6.5	17.5	8.0	21.1
50th	6.5	15.0	9.5	22.6	10.9	28.6
75th	9.7	21.9	13.1	30.2	14.8	34.7
90th	13.4	29.0	17.1	37.5	19.4	41.5

Table 2: Learning levels on Addition Fact Fluency: Number of facts answered correctly in a minute (ncpm)

	Grade 3		Grade 4		Grade 5	
Percentile	Govt.	Pvt.	Govt.	Pvt.	Govt.	Pvt.
10th	0.0	7.5	0	11.0	1.5	11.7
25th	0.0	8.5	4	13.3	5.5	16.0
50th	4.0	11.9	6.5	19.3	8.0	21.4
75th	6.5	17.6	9	23.8	10.5	33.1
90th	8.0	20.4	11.6	32.8	12.7	37.5

Table 3: Learning levels on Subtraction Fact Fluency: Number of facts answered correctly in a minute (ncpm)

A student is referred as fluent in addition facts and subtraction facts hereon if number corrects per minute (ncpm) is 20 or more. The private school students above 75th percentile in grade 3, above 50th percentile in grade 4 and above 25th percentile in grade 5 were fluent with addition facts. In government schools, even the students above 90th percentile were not fluent in both addition and subtraction facts in grades 3, 4 and 5 (except grade 5 in addition facts) (See Tables 2 and 3).

It was observed that 16.3% and 32.1% of grade 3 government school students did not answer any of the addition and subtraction facts correctly. 11.81% of grade 4 and 7.82% of grade 5 government school students did not answer any of the subtraction facts correctly. There was no student in a private school, who was not able to answer even a single item correctly.

The graph in Figure 1 explains the learning gaps in the fact fluency between government and private school students.

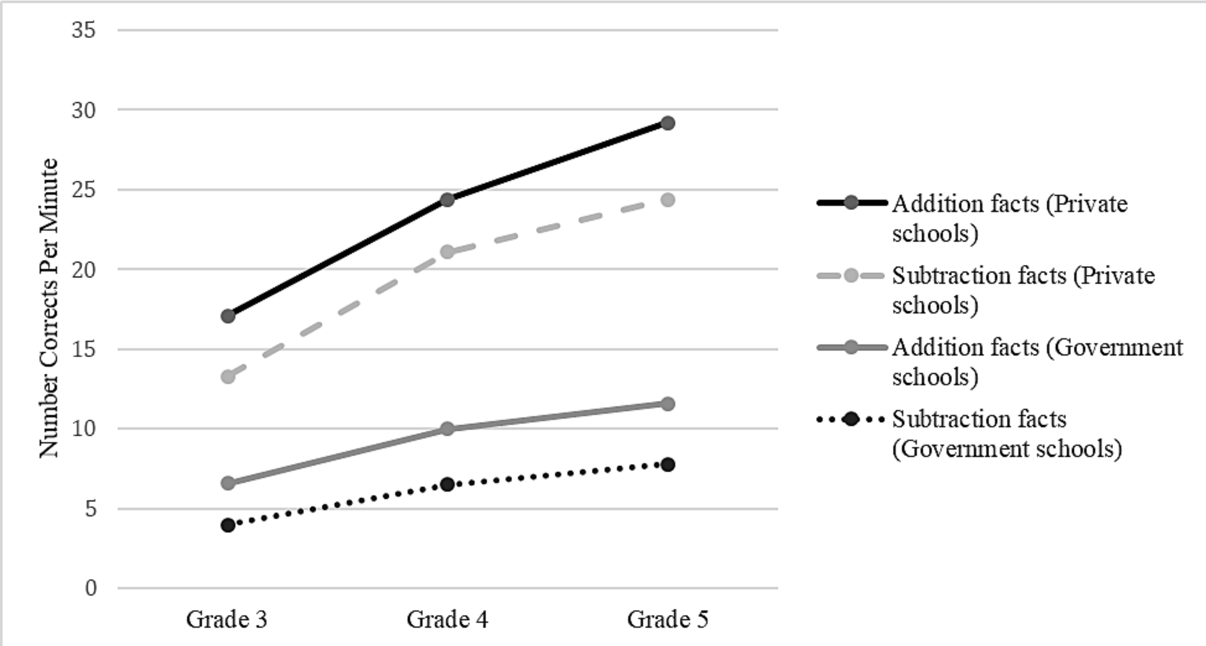

Figure 1: Addition and subtraction fact fluency across grades 3, 4 and 5

The authors of this paper have done some pilots to validate the assessments for foundational numeracy including the fact fluency in addition and subtraction facts in government schools and in particular measures for fact fluency in private schools. Around 60 students from 3 English-medium private schools in Bangalore (2 of them were high-fee private schools) and 60 students from 3 government schools in Karnataka, Rajasthan Gujarat and Rajasthan have participated in the pilots (their response data is not included in the above tables). The medium of instructions were Hindi in Karnataka and Rajasthan and Gujarati in Gujarati govt. schools. While doing the pilots, the authors not only just measured the fact fluency but also observed students and interacted with them after the test to understand their thought process in answering the facts. Apart from observations made if students counted on fingers or used counters on papers, students were explicitly asked for the strategy used by them to answer a few addition or subtraction facts after the completion of the timed tests. Apart from the metric number corrects per minute, the strategies used by students to answer the addition and subtraction facts also indicate their levels of fluency and help validate. Here we describe strategies observed in pilots.

The main strategies observed are, retrieving from memory, finger counting, counting using circles or marks and decomposition.

Retrieving from memory: The automaticity (answering within 3 seconds) whenever noticed is seen in addition facts for sum up to 10. The students have reasoned that they just know the answer when they were asked to share the strategy used for some of the addition and subtraction facts in the timed tests.

Verbal or finger counting: This is noticed more in government school students compared to private school students. In both the types of schools, students in the lower grade used finger counting and in the later grades, they are seen counting in their head verbally. More students used finger counting for subtraction than addition. Some students were using a minimum number counting strategy. For example, if they have to count 3 + 8, they are counting on 9, 10 and 11 from 8 instead of counting on from 3, in their head to answer as 11.

Count all strategy was noticed more with government school students and a few students in bottom 10 percentile in the private schools. To answer for say 5 + 3, they would count 5 fingers first, 3 more and then count all the fingers to answer as 8. Most of the private school students who used finger or verbal counting seem to be applying count on strategy (e.g. 7 + 3 as 7 in mind and counting on 8, 9 and 10 instead of counting 7 fingers and then 3 fingers to count all fingers finally).

Doubling: Some students in private schools and govt. schools seem to be comfortable with multiplication facts and they converted doubling fact to a multiplication fact (e.g. 8 + 8 as 2 times 8). This strategy is noticed in some students in 2nd and 3rd quartile private school students as well.

Decomposition: Mostly top 10 percentile private school students (students with a good score of number corrects per minute in the two fact fluency timed tests) seem to be applying this strategy of decomposing the given fact to an easier fact for which they have developed automaticity. This doesn't seem to be a traditionally taught method or logic. The students seem to be developing such strategies on their own. Some examples are given below.

Making it to pairs of 10: 3 + 8 as 1 + 10 (as 2 + 8 = 10); 9 + 3 as 10 + 2;

converting into easier facts: 5 + 7 as 10 + 2 (5+5+2); 7 + 9 as 6 + 10; 8 + 9 as 2×8 + 1 (doubling)

Count on for subtraction: Students are using finger/verbal counting more for subtraction both in govt. and private schools. But some students are using count on strategy. E.g. to answer 12 - 8, they may count 9, 10, 11 and 12 and then answer it as 4.

In both private and government schools, very rarely the relevant addition fact is used to answer the subtraction fact. E.g. 12 - 4 can be answered using 8 + 4 = 12 which can be seen in adults.

We found mix of strategies used by a single student in general varying as per the addition/subtraction fact rather than the same strategy used consistently for all the facts.

DISCUSSION AND CONCLUSION

The private school students above 75th percentile in grade 3, above 50th percentile in grade 4 and above 25th percentile in grade 5 were fluent with addition facts (ncpm greater than or equal to 20). In government schools, even the students above 90th percentile were not fluent in both addition and subtraction facts in grades 3, 4 and 5 (except grade 5 in addition facts). A considerable difference in levels of fluency (as indicated by ncpm) among students in private schools and government schools was found in all the 3 grades. The gap between the levels of fluency in private schools and government schools widened moving up the grades from 3 to 5.

The levels of fluency improved from grade 3 to grade 5 among students in both the government and private schools. A gap between levels of fluency in single-digit addition facts and related subtraction facts was found among students in both the government and private-schools in all the 3 grades. The gap did not narrow moving up the grades from 4 to 5.

We propose to use the measures developed to measure fluency in single-digit addition facts and related subtraction facts periodically and develop benchmarks for fluency. The measures to be made part of any standardized large-scale assessments on foundational numeracy. A technology-based assessment mode can be used to measure time taken to answer a fact better and hence the levels of fluency. In future, measures which focus on evaluating method (strategy) used to answer a fact can be developed for use in formative assessments in classrooms. These need not be timed tests.

Based on the observations on strategies used to answer facts, timed-tests could challenge students to think differently to answer quickly and hence they could think of newer strategies to solve the given fact. It is recommended that instructors use the proposed tests to measure the fact fluency in addition and subtraction and give lot more learning opportunities to develop fact fluency. They should nudge/challenge learners to develop strategies to answer facts quickly. Instructors can also give some scaffolding to make the students gradually move from count all to count and decomposition of numbers etc. For example, giving more practice with pairs of 10 might help them to decompose any other number combination into pairs of 10. Further research on instructional practices to develop fact fluency effectively and earlier in grades especially among government schools are proposed. Unlike in good private English-medium schools, students in government schools don't seem to develop automaticity in the addition and subtraction facts on their own. Hence is the need for intervention in the government schools to develop fact fluency. In another study by the authors, students in government schools were found to be struggling more in vertically adding or subtracting whole numbers compared to private school students. Lack of fact fluency and ill developed number sense may be able to explain this gap in proficiency on addition and subtracting whole numbers.

Joy Cumming, J., & Elkins, J. (1999) found that elementary aged students who were computing simple addition problems (not just single-digit facts) made the most errors in a miscalculation of the fact(s) involved and not with the addition algorithm. This re-emphasizes the importance of fluent knowledge of the addition facts for the development of the next level of arithmetical skills. When the curriculum and the national framework aims to achieve foundational numeracy by grade 3, the results on addition and subtraction fact fluency of government school students seem to suggest the need for effective interventions/learning opportunities. Children with low achievement on arithmetical computation may not only have poor strategic development but also poor memory development (Geary, 1993). Automaticity does not occur as frequently as for other children, and fact retrieval as a strategy is more erratic and error-prone when used. Without intervention, this does not appear to change substantially across the elementary school years (Geary, 1993, p. 349).

When most of the high fee private school students can achieve the desired fluency in addition and subtraction facts, the student response data shows low levels of fact fluency in government schools with hardly any student reaching the desired mastery. Not being fluent in single-digit addition occupies the brain's processing capacity and that hinders the child's ability to solve sophisticated problems and consequently to develop mathematical models. It has been suggested that number fact deficits are associated with general weaknesses in processing speed (Bull & Johnston, 1997) and in linguistic processes related to representing phonological information and retrieving information from long-term semantic memory (Ashcraft, 1992). The teachers and educators should acknowledge the importance of fact fluency and give enough exposure of these facts to the student to help them reach the desired levels.

It is recommended that curriculum developers and educators advocate the importance of fact fluency and devise efficient instructional strategies to achieve the same.

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GAME-BASED LEARNING TO RAISE AWARENESS ABOUT WATER SUSTAINABILITY

Parth Dhond[1,a,!] and Anisha Malhotra Dalvi[2,b,#]

[1]National Institute of Design, Gandhinagar, Gujarat, India.

[2]Homi Bhabha Center for Science Education, Mumbai, Maharashtra, India.

[a]he/him/his, [b]she/her/hers

[!]parth_dh@nid.edu, #anisha@hbcse.tifr.res.in

In this paper, we discuss the development of an engaging game "Full Tank", designed to sensitise students about water usage and preservation. We present an overview of the game and discuss the process of designing educational games using an endogenous game design approach. The game is inspired from real life scenarios which were then carefully converted into game elements, player interactions and game mechanics. Lastly, we discuss the game "Full Tank" in the context of developing another game titled "Gram" which is also aimed at sensitisation towards water conservation and usage at a community sharing level.

INTRODUCTION

Awareness about climate change, water security and biodiversity are among the various important and recurrent topics that are taught in the Environmental Sciences (EVS) classes in Indian schools. The topics are detailed out as students progress from primary to secondary school years. Specifically, under the theme of water, the school textbooks cover a range of issues like sources of water and its storage, water at homes and communities, drinkable water and its supply, etc. These topics are usually taught in schools using textbooks, lectures, documentaries or student activities. One can also find lesson plans and web-based games around this theme like 'One for All: a natural resources game', 'Name that resource', and 'Eco' (One For All: A Natural Resources Game, 2014; Activities to Help Kids Learn About Natural Resources, 2019; Eco, 2018). However, one may argue that infrastructure dependent games, be it physical or web based may not necessarily have a wide reach in India, owing to many reasons. Further, many of the existing games are easy to play for an older audience who are equipped with resources, both physical and technological. Lastly, the integration of domain-specific learning into play-based activities and games is not common and remains a challenge for educationists.

BACKGROUND: THE PROJECT AND CONTEXT OF THE GAME DEVELOPMENT

The game design case studies discussed in this paper come under the ambit of a longitudinal participatory action research project called School Science Research and Development (SSRD), involving a local school, its teachers, and students (Deshmukh et al, 2018). This project involves working closely with teachers all year round to develop lesson plans around the environmental science (EVS) and general science curriculum and supplement classroom sessions with fun, inquiry-oriented activities and worksheets, among many other methods. In this context, the focus of our project was to develop an engaging game based on design principles for the topics taught in Environmental Sciences.

Textbooks, lectures, documentary screenings, special camps and workshops are few of the common modes in Indian classrooms to teach about the water crisis and other environmental concerns. This is supplemented by co-curriculars like project competitions, debates and art/theater which also give students an opportunity to express their thoughts on the topic. Although, the intent of the textbook activities is to generate interest in the students and aid better understanding of the topic, there seems to be a gap. On one hand the textual content equips students with necessary information, but there are limited activities linked to real life experiences. Therefore, while the textbook chapters covered water related themes at a broad level, there was scope to introduce the same issues using more locally relevant examples with a playful approach. This presented an opportunity to design engaging activities through the use of contextualised games which can help students observe, record and reflect on their immediate surroundings. The motivation behind the game design thus was to bring awareness, provide a valid connection with the curriculum and extend classroom learning in a playful manner.

GAMES AS A MEDIUM OF LEARNING

Games are often described as organised play that is structured by a set of predefined rules and an obstacle-tackling goal (Klopfer, Osterweil & Salen, 2009; Schell, 2008). This hypothetical goal is designed in an artificial environment where the players willingly submit to the game rules, knowing that their gameplay and player interactions may result in success or failure. Research has often highlighted the importance of play and games in learning (Granic, Lobel & Engels, 2014; Cooper, 2014). Moreover, when interacting with young children, play-based (Vygotsky, 1978) interventions, activities and games tend to captivate them and direct their attention to the concerned issues (Malone, 1981; Sedig, 2008). Games as a medium of learning have the potential to allow for accommodating complex information, breaking it down into game elements, presenting the content in the form of a plot, and challenging tasks and rewards associated with player actions. Game-based learning has been reported as beneficial for students not only from a learning perspective but also from the point of view of developing integral skills and attitudes such as risk-taking, accepting failures, healthy competition, tackling uncertainty and problem-solving (Klopfer, Osterweil & Salen, 2009).

Designing an educational game can be challenging as compared to casual games as it has a cognitive learning goal or attempts to attain a certain behavioural change. The rapid advances in the edutainment industry and in the development of learning games may at times overlook the contextual learning-play integration and may inadequately coat the educational content with superficial game-like elements and present it as play-based learning. In the domain of serious and purposeful game design, such addition of game-like elements is known as chocolate-coated-broccoli (Habgood and Ainsworth, 2011). The range of game-elements commonly include non-contextual use of characters, labels and cosmetic visuals coated on top of popular games such as Snakes and Ladders or Monopoly without altering the game play and structure. Studies on purposeful learning games have emphasised the need for appropriate integration of learning content and game play (Ke, 2016). While designing purposeful games, game designers consciously direct the actions of players and player interactions with the hope of initiating a subconscious behavioural change.

Endogenous game design is a category of designing purposeful games where the game play emerges from the content to effectively integrate learning with play. Very often, in education, we see learning content being gamified with superimposition of unrelated content on gameplay (Athavale & Dalvi, 2019). The design approach of endogenous games is in harmony with the learning content, and this is what makes this game design effective. The gameplay makes learning and playing go hand in hand (Malone, 1987; Habgood and Ainsworth, 2011). An attempt towards an endogenous game design approach is taken by referring to the state board curriculum textbooks to develop play-based learning activities on chapters from the Environmental Studies textbooks. In the process of designing games, unique aspects of the topic of water distribution were studied and translated into game elements and mechanics.

OVERVIEW AND DESIGN OF THE GAME 'FULL TANK'

As per the Maharashtra State Board syllabus (SCERT), EVS chapters in grades 3 to 5 include topics like 'Our need for water, Where does water come from, Storage of water, Water safe for drinking, Water for every household. During the initial school visits and student interactions, we observed that the textbook and other students' activities could be designed to accommodate student inquiries driven from their observations of their surroundings. This led to the conceptualisation of the 'Full Tank' game, aimed at enabling students to articulate and share their observations about water usage with their peers and teachers. It has been designed with an attempt to make students aware of how water is consumed in their immediate surroundings. The game is designed for 2-3 players in the age group of 8 to 12 years old.

Water tanks are used as a common storage option in many Indian households. The idea behind having a tank depicted as a representative scale, is to indicate that water though renewable is something that can become scarce and at times get exhausted. The scale tries to show that various human activities, as depicted in the 'Water Activity Cards' can have positive or negative effects on the water level. The daily chores/activities of the household are presented on cards with which the game is played, and alternative water usage options are given for the same chores. For instance, for a "Cleaning" task there are two options provided, one which results in water wastage (using a hose/pipe) and the other which helps in using less water (using a mop). Thus, water consumed while doing various activities affects the water level on the water tank. These fluctuating water levels in turn gives an opportunity to the players to assess which activity may preserve or waste water. The elements of the game are discussed below (Figure 1):

Figure 2: Game board (left) and water activity cards (right) of the Full Tank game.

The water tank scale- A measuring unit for water (0L till 180L) used as the game board to play on and to depict the water levels for each player. This range was chosen as an optimum figure based on the number of water activity cards and the rise/fall values assigned to them.

The water activity cards- The content of these cards was derived from everyday practices which involved water usage, which may either result in conservation or wastage of water. The identification of these chores was a combination of both brainstorming over common practices and extension activities provided in school textbooks. Through these activity cards, situations in which water is typically consumed in different quantities have been gamified and described in a playful manner. This in turn affects the water in the water tank scale. There are additional Do-It-Yourself (DIY) cards provided for students to observe their surroundings, write new water related activities and their usage on the playing cards and use those cards to play. The game thus has an aspect of novelty, personalization and scalability.

Each activity card has the following information on them: Type of activity - which uses water; Specifics of activity - in which context an activity is carried out; Litres of water used in this activity; Fall/Rise of water in Water Tank Scale due to this activity; Reason behind the Fall/Rise of Water.

Markers - A marker for each player that shows the rise/drop of water in a water tank.

Game Play: Players represent themselves with unique markers on the game board. All the players start at the middle of the water tank, from where they can either move up or down as per the activity cards. Each player picks one activity card in turns and accordingly places the marker on the water tank scale. This playful approach behind the rise or fall of water on the tank, grounded in real life situations, is the main mechanic in the gameplay.

End of game: The game ends when a player reaches '180L' or '0L,'. But if no one reaches 180 or 0 even after the cards are consumed for the second or third time, then the player who is at the top of the water tank scale wins.

Figure 3: Playtesting of Full Tank game with middle school students in Gujarat.

The game was play-tested with students with minimal facilitation. They were informed about the rules of the game and that the game is based on their surroundings and water consumption. It was observed that they enjoyed playing the game together. They liked the simplicity of the game, the fact that two approaches of water usage for the same purpose were shown on the cards and accordingly they got to move their markers up and down on the tank scale. This made them aware that being water-conscious is important. The initial rounds of testing (Figure 2) also revealed that the students only played to win and focused on the movement of markers based on the value of litres written on the cards. They often ignored the information given on the cards and the relevance of water consumption in various situations. They also did not pay attention to the reasons for the rise/fall of water in the tank. Post-testing certain changes were made in the game play. Now, the revised rules required players to pick one card at a time and read aloud the water activity and the specifics of the activity. The others have to guess if the marker would rise or fall on the water tank scale. Players then read out the rest of the card and accordingly move their marker up (rise) or down (fall). This additional interaction between the students provided little more engagement, peer interaction and learning. Since play testing also indicated that the game did not necessarily finish with one round of playing, reshuffling and reusing the cards was introduced. In the revised rules, reshuffling can take place at a maximum number of 2 (for two players) or 3 times (for three players). At this stage, the players did not design any new cards to play with. Instead, they played with the set provided to them. The teachers can probably intervene here and encourage students to observe their surroundings and help them to design their own cards to make the game more contextual. The latest version of the 'Full Tank' game can be accessed on the Design and Technology Education group's website: https://dnte.hbcse.tifr.res.in/lab-activities/

SUMMARY

The objective of our project was to look at alternative media to aid active learning, engagement, and play-based learning methods for maximum student participation. Water forms a very important topic in the Environmental Sciences and science textbooks from lower to higher grades. The game "Full Tank" is an attempt to introduce the issues related to water conservation in one's surroundings through play. In the game, students need to pay attention to their surroundings and identify ways in which water is being wasted or conserved. As the game is played, it is hoped over time, students will realise that these small conservation efforts when implemented at the community level contribute significantly to safeguarding this life-sustaining natural resource. The most important feature of the game is that there is an option to make your own 'Water Activity Cards', so that players can bring in local experiences and add them to the game in their local languages, thereby enhancing engagement and the scope of the game. Some of the possible skills students may develop by undertaking this card-making exercise include, observation of surroundings, problem identification, looking at issues from multiple perspectives, communication and collaboration.

WAY FORWARD AND AN OVERVIEW OF THE GAME 'GRAM'

The understanding of water as a resource broadens from an individual's consumption to community sharing and distribution, as one moves up from the lower to higher grades. Details such as different sources of water, its ever-increasing consumption and distribution systems are elaborated. Building on the basics of community sharing of water, cooperation, and water sustainability, another game titled" Gram" (meaning society/village) has been conceptualised where a hypothetical village is to be provided water and the challenge is to make the village water distribution efficient via players cooperation and strategy. The elements of the game (Figure 3) are discussed below:

Figure 4: Game elements of the "Gram" game

Game elements and gameplay: The game consists of 15 colony cards and 30 water cards. The colony card depicts the occupations that are practiced in villages namely markets, agriculture, transport, handicrafts, healthcare etc. and shows the number of families dependent on that occupation. The water card shows the type of water source that can provide water to the village. These can vary from natural sources like rivers and lakes to human-made sources such as dams, overhead tanks, wells, borewells and tankers that cater to water demands of people. The selection of colonies and distribution of water within the resources is inspired by real life scenarios. Players must divide themselves into 3 teams. Each team may have 2-5 individuals. The colony cards and water cards are distributed equally amongst the three teams. Following certain rules, each team has to organise their cards by linking water cards for each colony card such that it best meets its water demand. Once this stage is achieved by all the teams, the teams work together as one unit and ensure that the water requirements of the other teams are also satisfied. This cooperative effort to satisfy water needs of all the teams is referred to as playing together as a 'Gram'. In this advanced stage of the game, the decisions by the team with the most water resources of the Gram will decide the outcome of the game. If played this way, the game will finish when 3 teams together reach the best possible solution to address their water requirements. On the other hand, if a Gram has more than seven colony cards that are water deficit, then this ends the game. This reflects the poor water situation of the Gram.

User testing and evaluation: The game is currently in the evaluation stage and is being play tested with secondary school students (Figure 4). The principles and dynamics of the game are unique for Indian classrooms and need careful testing and analysis for it to be an effective learning aid for students.

Figure 5: Paper prototyping the game 'Gram' and testing with students.

DISCUSSION

In this paper, we discussed game-based learning and the process of game design based on effective learning-play integration. Full Tank is a simple game focused on everyday usage of water. The game tries to bring to the fore small actions by individuals that either lead to water wastage or water conservation. The visual metaphor of using a water tank as a game board and students observing the rise and fall of water was found to be an engaging and playful way to learn about water consumption. We are aware that, in reality, water conservation is not so simplistic and there are multiple factors that affect water usage. However, this game simplifies the issue for young children and aims to raise awareness about the connection between our actions and water wastage or conservation. On the other hand, the game Gram is more complex in its nature, theme, mechanics, and game play. It is a cooperative game where the focus shifts from individual actions to working together as a team towards a shared goal of making the Gram water-sufficient and facing the consequences of the actions taken together. The objective of these games is to make students aware of how water fares in daily use in small households and in communities. In future, it will be interesting to observe how playing such games can influence students' current understanding of these environmental topics and bring about a certain behaviour change in them.

The games discussed in this paper are designed with the intention of having a larger reach as it will be available in English, Hindi and Marathi and because of its minimal dependency on resources. The design is frugal and scalable as both the games can be printed on paper, cut as per the instructions, arranged easily and played. The game mechanics are simple, based on real life situations and grounded in the information to be disseminated which can be adapted as per contextual needs.

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IDENTIFYING GAPS IN STUDENTS' UNDERSTANDING OF ALGEBRAIC IDENTITIES: TOOLS FROM INDIC KNOWLEDGE SYSTEMS

Vinay Nair

Chinmaya Vishwa Vidyapeeth, Ernakulam, Kerala, India.

vinay.cvv200153@cvv.ac.in

Getting a good foothold on algebra is a key component in school education. In India, students learn algebraic identities, methods to manipulate terms and solve linear equations in one variable in the 8th grade. However, many students face a challenge to get a deeper understanding of algebra (Kieran, 2006) (Van Reeuwijk, 1995). As a result, even if students memorise an identity like $(a+b)^2$ *they may not connect it to the sum of two expressions* $a^2 + b^2$ *and* $2ab$*. There are also students who cannot explain why* $(a+b)^2$ *must be a square number for integer values of* a & b*. Even with students who have this understanding, it is not easy to get them to solve problems of higher difficulty like expressing a number as a difference of two squares which can be solved using another identity* $a^2 - b^2$ *that they learn in grade 8.*

A pilot study was undertaken to identify such gaps in 8th grade students' deeper understanding of algebraic identities and their application in solving problems involving higher order thinking. The sample consisted of 8th grade students from two schools. Ideas, motivation and examples used were from the mathematics literature in Indic Knowledge Systems (like Brahmasphutasiddhanta and Lilavati) which are rich in problems that integrate arithmetic, algebra and geometry. During the study, in addition to observing their present understanding of algebra, students were also taken through an exploration in Pythagorean Triplets and word problems that involve application of mathematical concepts taught across different chapters in the 8th grade. The goal was to achieve deeper understanding of algebraic identities, enhance higher order thinking skills (HOTS) and enable transfer of knowledge across different chapters learnt in geometry and algebra. These goals on HOTS come under strand 2 and 3 of the outcomes to be achieved in mathematics education as explained in the National Achievement Survey 2021 (NAS, 2021). This paper presents the findings and analyses of the pilot study.

INTRODUCTION

> 'Mathematics is the study of patterns, and a mathematician is a maker of patterns' ~ G. H. Hardy

There are many mathematicians who agree to the above statement by Hardy and have reemphasised the statement. To understand and express patterns, one of the best mediums is algebra. Just as a student learning to play the piano must master the notes of piano, to learn mathematics and its applications in various domains, a student must learn the language of algebra. While there is a lot of research on innovative methods to teach algebra, it remains a challenge for many students to get a good grip on algebra as per various studies conducted elsewhere (Kieran, 2006). Even though all students learn rules/procedures in algebra, very few understand the reason why these rules work the way they do (Van Reeuwijk, 1995).

National Achievement Survey 2021 (NAS, 2021) points at three strands that we ought to achieve through mathematics education – Applying the concepts learnt in problems that are straight forward; analysing and interpreting the data given in the problem, connecting the dots and integrating different pieces of information to solve the problem; and developing creative skills like generalisation, handling complex information and dealing with intelligent manipulations to solve the problem.

By learning only the rules/procedures, strand 1 is achieved but not much of strand 2 and 3 which involve Higher Order Thinking Skills (HOTS), also referred to as "higher goals" in NCF 2005. Inability to get a good footing on strands #2 & #3 is being referred to as a gap in this paper.

BACKGROUND

Students from the CBSE board learn algebraic identities, the Pythagorean theorem and solving linear equations in one variable, in three different chapters (2, 6 & 9) in 8th grade NCERT Mathematics textbook. However, their exposure to problems where they must pull out knowledge from different chapters is very limited. One of the reasons for low exposure to such problems is that mathematical concepts are generally presented in a compartmentalised way in the textbooks and hence taught the same way. This compartmentalisation does not give room to include problems at the end of a specific chapter as the problems demand combining concepts from more than one chapter. As a result, many students are unable to integrate concepts across chapters while solving a new problem that involves fluency in the topics. While one may think that this challenge is faced only by students who find mathematics difficult, it can be observed that even students who like mathematics find it difficult to make connections between topics. The study aspires to check the depth of students' understanding of algebraic expressions and identities, and response to problems involving combination of concepts across the textbook.

LITERATURE REVIEW

Algebraic understanding

The role of algebra in building foundations of higher mathematics is undeniable. Every student should be having access to skills like algebraic thinking, algebraic reasoning, reading graphs, etc. (Van Reeuwijk, 1995). Sadly, many students struggle with algebra. To be more specific, many struggle with the transition from arithmetic to algebra that Subramaniam & Banerjee (2011) talk about and understanding the abstraction involved in algebra (Star, 2015). They also struggle to achieve the higher order thinking of transfer that Anderson and Krathwohl (2001) talk about, even though they are able to recall the concept learnt. While the narrow aim of mathematics education is to teach mathematical concepts, a higher aim is to develop mathematical thinking and HOTS through various mathematical concepts (NCF, 2005).

Learning theories and Teaching methods

A few decades ago, behaviorist approaches were used in the classrooms where the students were rewarded or punished based on their achievements in the class. However, this approach has been replaced by other learning theories like the constructivist approach as proposed by many like William James, John Dewey, Jean Piaget, Maria Montessori. Constructivism focuses on helping students construct knowledge by themselves and actively engaging them in the process of learning as against being passive learners in the classroom (Eby et al., 2006). NCF 2005 talks highly about merits in using the constructivist approach in classrooms.

Guided discovery learning approach is similar to constructivist approach where students are hand held to construct knowledge (Cruickshank et at., 1995). NEP 2020 (Section 17.8) emphasises on the need for a discovery-based learning approach to develop critical thinking.

NAS 2021, that provides the assessment framework for mathematics and other subjects at school level, stresses on three strands (mentioned in the introduction) that ought to be achieved through mathematics education in the 8th grade. Strand 1 focuses on the narrow goals, and 2 and 3 on the higher aim as stated in NCF (2005).

BACKGROUND OF THE SUBJECTS

22 boys and 20 girls of 8th grade from two schools from the DAV group of schools, Chennai, following the CBSE board opted to take part in the study. Out of this, 9 of them dropped out and 33 of them continued until the end. Of the 33, 5 of them attended the sessions but did not submit any assignments. Hence, they have been excluded from the analyses. A student attended the sessions and submitted the assignments but did not appear for his school assessment exams. He has also been excluded from the analyses as the school assessment scores were taken for comparison. Hence, 27 students (15 boys and 12 girls) have been considered in the study.

The school mid-term assessment of 8th grade indicated that the group was heterogeneous in terms of their ability in mathematics. The students came from families where both the parents (except in the case of two) had at least completed graduation and in the case of the other two of them, one of their parents had completed graduation. Five-point scales were administered to the students to rate their love for mathematics. About 41% of students gave the rating of 5 (out of a rating of 1 to 5, where 5 being the best) as their love for mathematics and 22% showed the lowest rating as 3 for their love towards mathematics.

DEFINITION OF VARIABLES

“Assignment scores” referred to total score in all the assignments that students have turned in, converted into percentage after scaling by the maximum score of the assignments turned in. “School assessment” is the 8^{th} grade mid-term school assessment scores of the students. “Assignments count” is the count of assignments turned in by the students out of 10 assignments. “Love for Math” is the self-assessment of students’ opinion for their love towards mathematics on a 5-point scale where 5 being Math their favourite subject which was collected on the first day of the study. “Responsiveness” is the investigator’s (who was also the faculty) assessment of students’ responsiveness in the class on a scale of 1 to 3 where 3 being the most responsive and 1 being the least. A score of 3 was given to students who were eager to answer or not hesitant to ask doubts. 2 was given to students who responded only when they were called upon. 1 was given to those who hardly responded in the class on their own or when called upon.

The students were split into two groups in the analyses by taking a median split on their mid-term school assessment scores of 8^{th} grade. The ones who came in the top 50% of the scores are referred to as “High school performance” and the others as “Low school performance”.

RESEARCH METHOD

The study examined the students’ learning, learning gaps in mathematics of grade 8 and HOTS. A module that constituted topics and ideas from the mathematics literature in the Indic Knowledge Systems (IKS) along with a guided discovery approach was presented to the students in the form of 10 Live online sessions spread across 5 weeks (2 sessions of 90 minutes each per week). The IKS component consisted of topics from the works of the famous 7th Cent.

Indian astronomer Brahmagupta and from the celebrated text of the 12th century mathematician Bhaskaracharya II, Lilavati. Topics from Chapters 2, 6 and 9 from the NCERT textbook were taken in the study and ideas from IKS were used for identifying the learning gaps in the chapters as well as building HOTS used for problem solving.

A total of 10 assignments were given to the students during the course and feedback for their work was given by the researcher (who was also the teacher) without any grading. The problems in the assignments were mostly based on topics, thinking skills and problem solving strategies discussed during the sessions. Some of the assignments demanded only to list possible solutions, while the rest involved questions where students had to use cognitive complexity that come in the top end of the revised Bloom's taxonomy. The students were encouraged to submit the assignments before the following session, but no incentive was given to students for submission of the assignments. The idea was to check the motivation of the students to learn where marks or any other incentive would not become a variable to consider in their performance assessment. Participants were encouraged to try the problems that involved exploration and submit their work to whatever extent they could do. The sessions focused on introducing topics from the IKS that would appear in forms that are new to the students but they had learnt in school the necessary concepts needed to solve those problems. The places where the students could not see the application were noted and through the process of guided discovery the investigator studied if the students were able to fill in their learning gaps.

Even though students received only feedback and not scores to the assignments, the investigator scored every question. The maximum score for each assignment was not the same and not every student turned in every assignment. For analyses, only those assignments' scores that the students had turned in were considered and the scores were scaled by sum of the maximum scores of the respective assignments. The analyses were mostly qualitative through observations and interviews but were also substantiated quantitatively through univariate analyses.

FINDINGS

Qualitative analyses

It was observed that even though students had learnt the three main algebraic identities, they were not able to relate to them when presented in a different form. Initially the students were asked to express some natural numbers as a difference of two squares, followed by if there could be more than one way to express a number as a difference of two squares and if so, how many ways exist? The students came up with claims and observations while they generated the data, but none of them were able to transfer the knowledge and apply the identity $a^2 - b^2$. Using guided discovery, some of them eventually saw the application of the identity which gave hints to many others in the group resulting in students themselves identifying their learning gap and filling it up taking the current learning as reinforcement. However, there were still students who could not understand how $(a + b)(a - b)$ is a product of natural numbers.

The second gap that was identified was through the topic of Pythagorean Triplets (PTs). In the 7th Cent. CE, Brahmagupta (Heroor, 2014) had given three algebraic expressions with which one can generate PTs. They were: $m^2 + n^2$, $m^2 - n^2$ and $2mn$; $m, n \in N$ & $m > n$.

Students were asked to generate PTs using these expressions. Once they generated a few PTs, they were asked to make observations, classify and categorise based on patterns observed, and construct claims based on the observations. The students enjoyed this exercise.

2. Generate Pythagorean Triplets using the expressions $m^2 - n^2$, 2mn and $m^2 + n^2$ for the below values of m & n (feel free to use MS Excel to do this if you know how to use excel). The first one is done for you. Fill in the rest of the table.

m	n	$m^2 - n^2$	2mn	$m^2 + n^2$	Triplet
8	1	63	16	65	16,63,65
5	2				
7	4				
9	3				
10	4				

3. In the above table, take every triplet and **add** the number in the green column with the number in the yellow column. What do you get in every case? Do you observe something? If so, what is it? Why do you think it is happening?
4. In the above table, take every triplet and the number in the yellow column and **subtract** from the number in the green column. What do you get in every case? Do you observe something? If so, what is it? Why do you think it is happening?

Image 1: In one of the assignments, the questions shown in image 1 were given.

In image #1, question #3 (& question #4) could have been asked as – What do you see in the result when the numbers formed by $m^2 + n^2$ and $2mn$ are added? But then, many students would have found the answer because they are seeing the identity $(m + n)^2$ is the form of algebraic expressions that they are familiar with. To test if the students were able to see this identity when not stated explicitly, the columns were coloured as shown in Image 1, and the students were asked to add the numbers in yellow and green cells of any row and see what's special about the answers for all the rows. Surprisingly, no student was able to relate the identity of $(a + b)^2$ to this question. Similarly, they could not relate $(a - b)^2$ to question #4. In other words, students were able to achieve strand 1 of NAS 2017, 2021 but not strand 2 or 3.

Students were also introduced to problems that involved HOTS like reverse thinking. While students could generate PTs using two variables m & n, it was challenging for many to do the reverse, i.e., to find the values of m & n for a given PT. Such questions involving HOTS where students had to resort to problem solving strategies and heuristics were new to most students. The initial approach by many was to do trial and error to find the values of m & n. However, eventually when they saw larger PTs, they realised that methods had to be devised to solve them. They slowly resorted to observing patterns in PTs and doing a reverse thinking to solve if the PT followed those patterns. They used observational generalisations to solve problems in numbers that involved "reverse thinking" but not in the case of algebraic identities which highlights the gap in their understanding of algebraic identities.

While many used observational generalisation, some saw that $2mn$ is always even. They took the even number in the PT and backtracked it to find possible values of m & n by factorising mn. This method involved trial and error but was useful in PTs where there was exactly one even number. However, they saw that neither of these techniques were helpful when the PTs became larger or when all terms were even. Here is when they appreciated the utility of algebraic identities where they could just add and subtract two of the expressions $m^2 + n^2$ and $2mn$ to arrive at equations in the form of $m + n = X$ and $m - n = Y$. As the students were not introduced to solving equations with two variables simultaneously, about half of them used heuristics and constructed the knowledge necessary to solve two equations with two variables to find the values of m & n. It was reassuring to see how constructivist approach can help in constructing knowledge on topics that are taught 2 years later.

One of the most challenging aspects for students in problem solving in mathematics is when they encounter word problems. The students were introduced to word problems from Lilavati like the Snake-Peacock problem & Broken bamboo problem (see Appendix). Most of the students found these problems extremely challenging to attempt. The problems demanded constructing a rough figure, translating it into algebraic expressions, followed by application of algebraic identities, forming equations and solving them using what they had learnt in the chapter of linear equations in one variable. As compared to the earlier problems of factoring a number and PTs, combining knowledge from multiple chapters and apply them to one single problem, was relatively hard for many. These aspects fall at the top end in the Revised Bloom's Taxonomy. One of the reasons inferred from the students' work was that for the earlier problems on identities, they had multiple strategies and heuristics to solve. However, for a word problem like the ones from Lilavati, the approach was linear. A rough figure had to be constructed which demanded visualisation. The second challenge was to take in necessary information from the question and assign values in algebraic terms to the side lengths of the geometric figures formed. The third challenge was to bring together the necessary knowledge from three different chapters. The word problems from Lilavati was a culmination of the topics discussed in the sessions where students had to transfer their knowledge of algebraic identities, Pythagorean theorem and PTs, solving linear equations, synthesise all the data, convert the data into a rough figure and solve the problem.

Quantitative analyses

	Count	Mean	Sd	Q1	Median	Q3	Min	Max
Assignment scores	27	61.439	18.902	44.643	65.909	73.684	30.460	100
School assessment	27	68.000	17.856	57.000	68.000	84.000	32.000	99
Assignments count	27	5.148	2.365	4.000	5.000	7.000	1.000	9
Love for Math	27	4.185	0.786	4.000	4.000	5.000	3.000	5
Responsiveness	27	2.111	0.934	1.000	2.000	3.000	1.000	3

Table 1: Table of scores, assignments submissions, love for math and responsiveness

Table 1 indicates the count of the students, mean, standard deviation, quartiles 1, 2 & 3, min and max scores/numbers. Maximum assignment score of 100 is of a student who had submitted only one assignment with a perfect score. 73.684 at Q3 in the assignment scores shows that the distribution of the students is not skewed and that there are no outliers in the course. Median and mean in the school assessment being 68 reinforces this fact. "Love for Math" being 4 and 5 in Q1 to Q3 shows that students' love for the subject was independent of their scores.

	Low school performance (N=14)		High school performance (N=13)		
	Mean	SE	Mean	SE	Diff. in mean
Course performance score	0.533	0.049	0.702	0.044	0.169**
No. of assignments turned in	4.286	0.597	6.077	0.615	1.791**
Love for Math	4.071	0.221	4.308	0.208	0.237
Responsiveness	1.786	0.261	2.462	0.215	0.676*

*** indicates $p<0.01$, ** indicates $p<0.05$, * indicates $p<0.1$

Table 2: Mean, standard error and difference in mean of course performance score

Table 2 depicts two groups of the students based on their performance school assessment. Mean and standard error for both groups were computed on course performance score, assignments count, love for math and responsiveness. A univariate analysis revealed that there was a significant difference between the two groups at 5% significance level when assessed through the course assignments' score. Assignments count showed a substantial difference in the groups at 5% significance level. There was a difference between the two groups at 10% significance level in their responsiveness which could be the result of self-efficacy. Nevertheless, when it came to love for mathematics it was evident that both groups showed no significant difference.

Most students who scored well in the school assessment. While the others were motivated to learn, they found it difficult to achieve the outcomes of strand 2 and 3 of NAS 2021.

CONCLUSIONS

Research by Van Reeuwijk, Subramaniam K, Star J.R., and several others highlight the challenges faced by students in aspects like transitioning from arithmetic to algebra, algebraic thinking and abstraction in algebra. The present study augments the above said aspects by using tools like Brahmagupta's expressions to generate PTs for identifying gaps that exist in deeper understanding of algebraic expressions and identities, and also by introducing problems from texts like *Lilavati* that demand integration and transfer of concepts learnt in different chapters. Below four points summarise the conclusions from this study.

- Even though most students could memorise the three algebraic identities, even the best amongst them lacked deeper understanding and application of the identities. In schools, students are shown physical and pictorial representations of algebraic identities to reduce the abstraction of algebra, but the present study highlights that this may not be sufficient.
- Using Brahmagupta's expressions for generating PTs, helped achieve a deeper understanding about algebraic identities amongst who scored well in their school assessments. It also helped in identifying gaps in understanding of algebraic concepts and symbolism in students; and the students got motivated to generate & categorise data, identify patterns, construct claims and conjectures, and come up with heuristics to solve problems. These helps achieve HOTS referred in Strands 2 and 3 of NAS 2021.
- HOTS can be developed when students are exposed to problems involving strategies to solve. Students who were performing well in mathematics could use HOTS faster than the ones whose performance in mathematics was lower but were motivated to do mathematics.
- The word problems from *Lilavati* that involved application of concepts like Pythagorean Theorem, algebraic expressions and identities, solving equations in one variable and visualisation to a great extent, provided opportunities for students to see the integration of different concepts in mathematics. However, the problems need to be more contextualised to time and place for students to get a better visualisation of the problems.

Most of the research on mathematics from the IKS is from a historical perspective. More studies like the present one can bring in perspectives of using IKS in the classrooms to check if it can augment in reducing learning gaps and enhancing clarity & mathematical thinking.

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Appendix

Word Problems from Bhaskaracharya II's Lilavati (Rao, 2014)

Broken bamboo problem (Verse 150): "Well O Mathematician! If a bamboo 32 cubits long broke at one place due to the speed of the wind and its tip touched the plane ground 16 cubits away from the root, tell me how many cubits away from the root it (bamboo) broke?"

Snake-peacock problem (Verse 152): "Snake pit is at the foot of a pillar, 9 cubits high. On that is a playful peacock perched on its summit. Seeing a snake at the distance of thrice the pillar gliding towards his hole, he pounces obliquely upon him. Say quickly at how many cubits from the snake's hole they meet, both proceeding an equal distance."

Lotus problem (Verse 155): "In some lake occupied by ruddy geese and cranes in the water, a tender lotus top half cubit above the water is blown by the wind. Moving very slowly it is immersed 2 cubits away in it. Tell (me) quickly O mathematician, how much the depth of the water is."

Two apes problem (Verse 157): "Some monkey coming down from a tree 100 cubits high came to a well 200 cubits away. Now another monkey quickly jumping up a little from the tree came diagonally to the same spot. If their distances covered are the same, O learned one, if you have worked hard in mathematics (then), tell me quickly how much (high) the jump was?"

INTEGRATION OF PUBLIC HEALTH AND PROPORTIONAL REASONING-A DEMAND OF TIME

Debasmita Basu[1,a,!]

[1]Eugene Lang College of Liberal Arts, The New School, New York, USA

[a]she/her/hers

[!]basud1@newschool.edu

The increasing obesity rate is a public health concern. Research suggests that food products rich in added sugar have significantly contributed to children's rising obesity rate and other cardiovascular diseases. Health professionals and researchers have advised a partnership between public health and mathematics education to address the issue of excessive added sugar consumption and its associated health hazards. They suggested that including topics related to food and nutrition in school mathematics education would generate students' awareness about food quality. Consequently, this study designed an integrated STEM module at the cross-section of proportional reasoning and added sugar and explored ways added sugar provides students with an authentic context to engage in proportional reasoning and how proportional reasoning helps students identify the quantity of added sugar present in different food products. Built on the theoretical framework of Realistic Mathematics Education (RME), this lesson was remotely implemented on three middle school students from different parts of the US and provided them with a natural platform to initiate conversations around the quality of food products. This paper presents the case study with one student for an in-depth examination of the student's interaction with the integrated tasks. It examines the effectiveness of the tasks for possible revisions for the future whole class implementation.

INTRODUCTION

Since the past few decades, an increasing emphasis has been given to expanding STEM education. Driven by a shortage of STEM workforce, many educators and policymakers worldwide have worked towards improving STEM education and retaining a higher number of students in STEM fields (Madden, Beyers, & O'Brien, 2016). Improved STEM education prepares a generation of students to become well-equipped to tackle complex economic, social, and environmental issues through scientific, mathematical, and technological interventions. Although STEM integration appears to be consistently emphasized by educators and policymakers, there has been much debate around the process of integration. While many proponents of STEM education focus on a multidisciplinary approach "involving concepts and skills in each discipline being learned separately but within a common theme" (English, 2017, p. S8), others advocate for a trans-disciplinary approach. This form of integration suggests "knowledge and skills learned from two or more disciplines applied to real-world problems and projects, thus shaping the total learning experience" (English, 2017, p. S8). This study identifies closely with the form of STEM integration that proposes that in a well-integrated STEM module, one subject matter serves as a context to learn another subject and thus makes learning meaningful to students. It hypothesized that such integration would effectively develop students' quantitative skills and help them apply their mathematical concepts to better understand the world around them (Roseno et al., 2015). Consequently, this study focused on the topic of health and nutrients. It explored how an integrated module, developed at the cross-section of added sugar and proportional reasoning, i) provide students with a natural meaningful context to reason proportionally, and ii) prompt students to use proportional reasoning to calculate the quantity of added sugar present in different food products and evaluate quality of food.

PROPORTIONAL REASONING

The proportional relationship is a multiplicative relationship between two quantities, where the ratio between the two quantities remains the same regardless of their actual measures (Lamon, 1993). It plays a pivotal role in students' mathematical development and paves the path to understanding advanced concepts in mathematics, architecture, nursing, and pharmacy (Cabero-Fayos et al., 2020). Although proportional reasoning is foundational to higher mathematics and science, students often struggle while reasoning between proportional quantities. They experience difficulties distinguishing between proportional and non-proportional situations (Lamon, 1993; Hilton, Hilton, Dole, & Goos, 2016) and employ additive thinking instead of multiplicative thinking to reason between quantities that are proportional to each other (Cramer, Post, & Graeber, 1993). Researchers have focused on several pedagogical and curricular aspects to strengthen students' concept of proportionality and identified that context plays a major role in improving students' performance in proportional reasoning tasks. According to Misnasanti, Utami and Suwanto (2017), authentic and meaningful contexts can help students in reasoning around proportional quantities and contribute towards students' "developing their own repertoire of sense-making tools to help them to produce creative solutions and explanations" (Ben-Chaim, Fey, Fitzgerald, Benedetto, and Miller, 1998, p. 271). With a similar goal in mind, this study provided students with a familiar problem setting of food. Since students "encounter food on a daily basis, whether it is related to comfort, social gatherings, family meals, or basic biological needs" (Duffrin, Cuson, & Phillips, 2005, p. 65), the study hoped that the familiarity of the topic would provide students with a meaningful context to engage in proportional reasoning.

ADDED SUGAR

Research shows that there has been a shift in children's and adolescents' eating habits in the past few years. Nowadays, children and adolescents frequently eat out and drink an overwhelming number of soft drinks, thus exceeding the recommended target energy level derived from fat and added sugar (Story and French, 2004). According to a report generated by the Sugars Task Force of the US Food and Drug Administration, in 1977-1978, an average adolescent consumed 62-84 grams of added sugar; the consumption increased by 42% to 92% in 1999 - 2004 (Welsh, Sharma, Cunningham, & Vos, 2011). Such high sugar consumption makes young adults more vulnerable to different health conditions such as obesity, type-2 diabetes, elevated blood pressure, cardiovascular, and other chronic diseases (Bray & Popkin, 2014; Stanhope, 2016).

To address the issue of excessive added sugar consumption, health professionals and researchers have advised inclusion of topics related to food and nutrition in school education (Follong et al., 2020; Author). Researchers such as James and Adams (1998), Hyman (2008), and Duffrin, Cuson, & Phillips (2005) advocated a partnership between mathematics education and public health. According to Duffrin, Cuson, and Philip (2005), "if students are engaged in hands-on, inquiry-based learning activities with food, they will be better prepared to demonstrate and apply math and science knowledge and understand both basic and clinical science, which will support a healthy lifestyle" (p. 65). However, such a collaboration between mathematics and nutritional education is limited. Hyman (2008) encouraged mathematics teachers to use food nutrient labels to design mathematical activities to make students aware of food quality. Hovland. et al. (2013) developed the Food, Math, and Science Teaching Enhancement Resource (FoodMASTER) project, where they developed a series of modules integrating food and health to teach different science and mathematics concepts. In consort with such efforts, this study developed the Food Fact module containing three integrated activities on added sugar and proportional reasoning. We hoped that the module would provide the participants with a meaningful platform to engage in proportional reasoning and initiate a conversation around added sugar present in food products.

THEORETICAL FRAMEWORK

This study is developed on the theoretical framework of Realistic Mathematics Education (RME). It is a "domain-specific instruction theory for mathematics" (Van den Heuvel-Panhuizen, & Drijvers, 2014, p. 521), which advocates connecting learners' mathematical learning with their daily life experiences and knowledge. RME suggests that, instead of introducing mathematical concepts through their symbolic representations and theoretical abstractions, if students are allowed to construct their mathematical knowledge through active exploration of authentic problem situations, then that would prepare students to communicate mathematically and make connections with each other and the real world (Freudenthal, 1991). Consistent with the principles of RME, this study has been motivated by the growing condition of obesity and children's awareness around it. We hoped that students' exploration of food nutrient labels would provide them with a natural and authentic context to engage in proportional reasoning and enhance their critical thinking skills about food quality.

METHOD

Participants and Settings

This paper presents a case study with one middle school student Lenny from the Midwest region of the United States. The goal of this pilot study was to investigate the effectiveness of the integrated tasks in engaging students in proportional reasoning as well as added sugar and utilize the results to modify the tasks for whole class implementation. The hour-long data collection was conducted through an online Zoom session due to the unprecedented situation caused by the novel COVID 19 virus. The session was audio and video recorded for data analysis. The meetings were password-protected, and the joining information was only accessible to the student and the researcher.

Task Design

The Food Fact module consisted of three integrated activities. At the beginning of the session, Lenny was asked to explore the nutrient labels of four food products, and record i) the number of servings present in them and ii) the quantity of added sugar in each serving (in grams) in a worksheet named "Count of Added Sugar" (Figure 2). The four food products used in this study were (Figure 1), 1) a packet of Oreo cookies, 2) a can of Coke, 3) a 40 oz container of Chobani Greek yogurt, and 4) a 15.3 oz box of Kellogg's Honey smacks breakfast cereals.

Next, the researcher asked Lenny to identify and reason if any of the food products were unhealthy. The researcher also introduced Lenny to the daily added sugar limit of nine teaspoons for males and six teaspoons for females as recommended by the American Heart Association (AHA) and informed him that one teaspoon contains 4 grams of added sugar. She asked Lenny to use the information to calculate the quantities of added sugar present in the four food products. The lesson ended with a brief discussion on how the activities have changed Lenny's perception of healthy food.

Figure 1. Nutritional Labels of Food Products

Count of Added Sugar

Name of the student: ___________________________

According to the American Heart Association (AHA), the maximum amount of added sugars we can eat in a day are as follows:

Men: 9 teaspoons
Women: 6 teaspoons, where 1 teaspoon = 4 grams of sugar.

Name of food product	Number of servings	Amount of sugar (in grams)/ serving	Number of teaspoons of sugar/ serving	Total teaspoons of sugar in the packet	Percentage of Daily Limit of sugar.

Figure 2. Worksheet-Count of Added Sugar

For task design, the study relied on the proportional reasoning frameworks suggested by Lamon (1993) and Cramer and Post (1993). The three activities developed in this study could be classified under missing value problems (Cramer and Post, 1993) and stretcher and shrinker activities (Lamon, 1993). For instance, in task 1, the researcher provided Lenny with three given pieces of information, one teaspoon is equal to 4 grams of sugar, quantity of added sugar (in grams) per serving, and unit serving, and asked him to calculate the number of teaspoons of added sugar present in one serving of the food products. This task is a missing value problem, where Lenny could use the three given pieces of information to calculate the fourth missing value. In task 2, Lenny was asked to consider the number of teaspoons of added sugar per serving and the total number of servings present in each food item to calculate the number of teaspoons of added sugar present in the whole package of the food items. This task is a stretcher and shrinker activity where Lenny could use the concept of scaling up and down and calculate the total teaspoons of added sugar. In task 3, Lenny was asked to consider the total teaspoons of added sugar present in each food product, compare them to the added sugar limit imposed by AHA and calculate how many servings of each food product would one consume to reach the threshold? The study identifies this task as a missing value problem. Although the study used the proportional reasoning frameworks to design the tasks, the researcher did not direct Lenny's attention to any specific concept of proportionality. During the lesson, she did not mention that the tasks would require him to use proportional reasoning. Consistent with the principle of RME, she wanted Lenny to construct his own mathematical knowledge through active exploration of the authentic context of food quality. As the study hypothesized, if the tasks did not lead Lenny to reason proportionally, the study intended to revise the activities and the guiding questions to engage students in proportional reasoning.

RESULTS

Task 1

In the first task, the researcher asked Lenny to calculate the number of teaspoons of added sugar present in one serving of the four food products. For each food product, Lenny used the two given pieces of information: the amount of added sugar (in grams) present in one serving of the food products and one teaspoon equal to 4 grams of sugar and set up a proportional relationship between them. Further, he performed a cross-product algorithm, an extremely efficient and commonly used method (Cramer & Post, 1993) and calculated the answer. For example, Lenny noted that each serving of Oreo contains 17 grams of added sugar, which is equivalent to 17/4 teaspoons of sugar. The researcher asked him to explain his answer to better understand the strategy Lenny used to reach the solution. Lenny said,

> First, we know that one teaspoon is equal to 4 grams, and we need to figure out, the 17 grams is how many teaspoons... So, basically, what I did was, um, I just said one by x is equal to four over 17 ($1/x = 4/17$) and cross multiplied them. So, you get 17 over 4x, you divide four on both sides, and you get x is equal to 17 over 4 ($x = 17/4$).

When the researcher asked Lenny why he divided one by x, Lenny said, "it's a comparison. So, on the top, we got what we were given. Um, so one teaspoon of one to four grams, but in the bottom, as a denominator, we're trying to see, we were trying to solve for it".

Task 2

After Lenny calculated the teaspoons of added sugar in one serving of each food product, the researcher asked him to calculate the total teaspoons of added sugar present in the entire packet. To solve this task, Lenny took two approaches. For some food products, he used the strategy of scaling up and down, while for some other food products, he treated the task as a missing value problem and used a cross-product algorithm. For example, to find the total teaspoons of added sugar present in the entire packet of Oreo, Lenny used the three pieces of given information, unit serving, teaspoons of added sugar/ serving of Oreo, and the total number of servings, and utilized the cross-product algorithm. Further, he explained his strategy by saying,

> There are 10 servings per container. (One) serving is two cookies. So, 10 times two is 20 (cookies)..., so two over 20 is equal to 4.25 over x ($2/20= 4.25/x$). Um, we could multiply it, but we could simplify it here. So, there's one. So, it's two over 20 (2/20). So, there's one in 10 (1/10). And we could say that x is .. the number of teaspoons in the total would be 10 times 4.25.

Lenny used a different approach for calculating the total teaspoons of added sugar in Chobani Greek yogurt. He calculated that each serving of Chobani Greek yogurt contains 3.5 teaspoons of added sugar, and since the entire container contains four servings; the total teaspoons of added sugar present in the whole container of Chobani Greek yogurt is "3.5 times four". When the first author asked Lenny why he multiplied 3.5 with four, he said,

> Um, because we found a one for one serving, and now we're just trying to find it for four servings because that's how many servings there are in a package. So, it's just one serving plus one serving plus one serving plus one serving is equal to the total cup. So, another way to put that is just, um, the 3.5 times four.

Lenny took an additive approach to calculate the total teaspoons of added sugar present in Chobani. Instead of multiplying 3.5 by four, he added the number of teaspoons of added sugar per serving four times and scaled up the quantity of added sugar per serving by the total number of servings.

Task 3

In task 3, Lenny was asked to compare the total number of teaspoons present in each food product and calculate how many servings of each food product would one have to consume to reach the daily sugar limit as suggested by AHA. To solve this task, although the researcher expected Lenny to reason proportionally, for some food products, Lenny did not reason between any proportional quantities. For example, when Lenny was asked how many cans of coke one drink would to reach the daily limit of 9 teaspoons, Lenny said, “the total teaspoons count in one Coke is 9.75. And for men it's, um, nine teaspoons. So, you would have to drink less than one bottle, less than one Coke”. His response does not provide any evidence that exhibits his proportional reasoning; rather, he compared the daily sugar limit of 9 teaspoons with the 9.75 teaspoons of added sugar present in one can of coke and concluded that since 9.75 is greater than nine teaspoons, one must drink less than a can of coke to stay within the daily limit.

DISCUSSION

The primary goal of this study was to design integrated STEM activities on proportional reasoning and added sugar and implement them on middle school students to study i) how such activities provide students with a meaningful platform to engage in proportional reasoning and ii) how reasoning between proportional quantities makes students aware about food quality. As the results suggest, the familiar context of added sugar helped Lenny reason between proportional quantities of servings and added sugar present in different food products and examine if cookies, breakfast cereals, yogurt, and soda contain higher than recommended levels of added sugar. Lenny was surprised by the quantity of added sugar present in food products which are generally considered healthy and good sources of nutrients. In particular, he was amazed by the amount of added sugar in the breakfast cereals; he said, "I found the honey smacks to be surprising because they have the second most sugar (out of the four food products); I was really surprised about the total teaspoons of sugar in the honey smacks."

Based on the findings of this pilot study, the researcher plans to revise the tasks and make them more student-driven for the future whole class implementation. For instance, instead of providing four random food products to the students, the module can start with students naming some food products they consume frequently and narrating their perceptions about the quality of those food products. Such revisions would not only make the tasks more relatable to the students but would also help the researcher identify how the tasks changed students' perceptions about food quality.

This study is a humble initiative toward integrating mathematical and nutritional science. As research suggests, more such initiatives are required to make mathematical learning meaningful to the students and make our future generation more aware of healthy life choices. In the future, the researcher looks forward to collaborating with nutrition scientists and designing similar modules that could be used in health education classes. Accordingly, this study encourages mathematics teachers to form a partnership with science teachers and leverage on the topics of food nutrition, so that food nutrition can serve as a meaningful context to learn mathematics, and mathematical reasoning helps students to make sense of their daily life experiences with food and make informed decisions around healthy life choices.

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INTEGRATION OF STEAM IN CHEMISTRY CLASSROOM

Puneeta Malhotra

Society for the Advancement of Education, Delhi, India

puneeta_krm@yahoo.co.in

National Education Policy 2020 foresees a paradigm shift towards an experiential classroom. Classrooms should be spaces to foster creativity and problem-solving skills thus making students future-ready. Our classroom should be a place where each and every learner is actively and creatively involved in the learning process. The learner should not fear the subject, but rather enjoy it. The author, a chemistry teacher, shares their experiences of implementing STEAM in their classroom. The author used a multidisciplinary approach to make the classroom an engaging space for learners. This paper is a qualitative description of teaching gas laws and the structure of atom in a senior secondary classroom.

INTRODUCTION

The conception of an alternative method to teaching chemistry in the classroom came when the author found that more than 50% of her students had alternative conceptions related to the particulate nature of matter (Malhotra, 2020). The author during classroom interactions and term-end assessments further found students were unable to apply concepts like gas laws to unfamiliar situations.

Interdisciplinary approach has been emphasized in research studies to deal with alternative conceptions, to motivate students, and to develop an interest in the subject. Integration of history and philosophy of science to study topics like the structure of atom, chemical bonding and periodic classification has been suggested in various studies. (Bent, 1984; Garritz, 2013; Cokelez and Dumon, 2005; Weinert, 2000; Nakiboglu, 2008). Recent studies (Abdoollatif & Narod ,2009; Khan, 2011; Tang & Abraham, 2015) claimed a significant improvement in motivation levels, interest in the subject, and performance of learners when taught using computer simulations and animations.

Taking inspiration from the studies, a transdisciplinary classroom was imagined, which integrated history, philosophy, music, and technology with science. The classroom envisioned by the author was an extension of STEM which typically focuses on separate content area through inquiry while attempting to draw relationships between the disciplines. (Herro & Quigley,2016).

Recently, we have moved from 'STEM to STEAM'. STEAM education has a short history of application, beginning in 2011, which means that STEAM practices are new, with limited research informing the field or suggesting how teachers should be trained. (Herro & Quigley,2017). STEAM has been showing promising results in evidence-based practices (BERA-report, 2017).

The latest National Education Policy (NEP 2020) promises to steer the curricula toward a more responsive, dynamic, and also inclusive form of education. With concern over rote memorization, NEP 2020 foresees a paradigm shift towards an experiential learning practice at school as well as in higher education**.** Classrooms have to be spaces for students to explore than simply memorize. According to DeJarnette (2012), Science classrooms need to exhibit more critical thinking, inquiry, and problem-solving activities that promote process skills rather than simply content knowledge. STEAM classroom promises to foster creativity and critical thinking.

However, there is little extant literature to guide educators to consider how this might be enacted in their teaching practices. STEAM teaching involves major shifts in teaching practice for many teachers; it takes time to refine and implement effectively (Quigley & Herro, 2016). A study by DeJarnette (2018) involving 50 in-service pre-school teachers of the north-eastern United States showed the reluctance to implement STEAM as a methodology. The 50 teachers were trained in STEAM implementation in the classroom but none of them implemented a STEAM lesson independently during the course of this study. The reason for the reluctance to incorporate STEAM was the planning required to implement it in the classroom. Traditional methodologies require little planning. To add to the problem is the fear of going wrong while implementing a new methodology. This fear of failure sometimes stops teachers from trying out novel methods.

Implementing STEAM in senior secondary chemistry classroom

The author, as an educator was reluctant to try STEAM with senior secondary classes but the literature backed the use of the interdisciplinary approach. They decided to experiment and use this approach for teaching chemistry to grades 11 and 12 learners. It was very challenging to develop a lesson plan which integrated STEAM. Also in the back of the mind was a constant fear of wasting too much time in such an experiment when the author had too much syllabus to cover. Still, they decided to give it a go in grade 11. Gas Laws and Structure of Atom were taught using STEAM. A description of the implementation of the lesson is described and shared in this paper.

Teaching Gas Laws using STEAM approach

In the initial years of teaching, the author used lecture method to define gas laws which was followed by solving numerical problems based on the laws. Lately, the author started using the data available in books to draw the graphs and interpret the relationship between pressure and volume to explain Boyle's Law. The same approach was applied to other laws. This was followed by solving numerical problems. The class was not too interesting, neither for the author nor for their learners. The author decided to use STEAM in her class. Planning of the lesson required a lot of research. No papers or lesson plans were available which could help them in implementation of STEAM at senior school level. The author decided to still go ahead and design a lesson plan from scratch. They came across simulations and applications of gas laws in latest technology. These were used to design the lesson.

The expected learning outcome was to understand and apply gas laws to new situations. The STEAM lesson on gas laws started without any mention of gas laws. The class was randomly divided into groups of 4 members each. The students were taken to the computer lab. The learners were given an observation sheet. Using simulations. They had to collect data by manipulating pressure, volume and temperature of gas. They were allowed to play with simulations on gases (https://ch301.cm.utexas.edu/simulations/js/idealgaslaw/) and study the effect of temperature, pressure and volume on gas particles. Learners used the data they collected to plot graphs for P (pressure) vs. V (volume) at constant temperature, V (volume) vs T (absolute temperature) at constant pressure. Based on the graphs, they were asked to draw conclusions from the data and graphs. Each group had to share their observations and conclusions which were used in the class to arrive at gas laws. The learners had a feeling of discovering something new and the energy in the class this day was immense. Learners used the technology to manipulate variables in the simulations, interpreted data using their understanding of Mathematics to arrive at the laws. The learners applied gas laws to solve numerical problems.

Next part of the STEAM lesson plan was very exciting but as a teacher, the author was a bit sceptical, the whole activity might fail. Still the success of the past three days spent on arriving at gas laws and applying these laws motivated the author. The groups were same as on day 1. Next was a trip to the lab. The learners were to make airbags. Material used was zip pouches, acetic acid and baking soda. The challenge here was to completely fill the zip pouch with the gas carbon dioxide, but no reactant should be left unreacted. There should be no limiting reagent. Students started asking the author what was the volume of the zip pouch? The author responded that they were supposed to find the volume. The groups of students started brainstorming. They came up with various hypothesis which were rejected and finally one group filled water in the pouch and measured the volume of water to get the volume of the zip pouch. It was a 'Eureka' moment for the group members. Other groups followed the same. The group members did calculations using stoichiometric and ideal gas equation to find the amount of reactants required. Slowly the class was able to make the zip pouch air bag. They applied their understanding of gas laws to a completely new problem. The class was full with excitement. Each and every child was involved in the process. This lab experiment took nearly one and a half hour (3 periods).

The result was a big motivation for the author. Now it was time to head to the playground. The learners had been given reading material on kinetic theory of gases beforehand. With a rope and music player, the learners and author were in the playground. Two groups were asked to combine. Each new group had to exhibit any one property of gases. Each member had to behave like gas particle and other groups were to guess the property exhibited. A rope was used to make a boundary to represent the closed vessel and music was played. Each group had maximum two minutes. One group exhibited the property of compressibility of gases by decreasing the size of the vessel, using the rope. Another group represented Brownian motion. There were collisions and lot of energy that could be seen in each 'particle'. Out in the playground, it was different learning experience and the author observed some learners who were not very active in the lab were the leaders for the day.

The teaching-learning process involved study of behaviour of gases (science) using simulations (technology) to create an airbag replica (engineering) using mathematical calculations (mathematics). The lesson also integrated music and dance to understand collisions between particles.

Teaching Structure of Atom using STEAM approach

Another example the author would like to share is use of history and philosophy of science (HPS) approach to teach the structure of atom. In a traditional classroom also a historical journey to trace the understanding of the structure of atom is followed but it is mostly a quick recap of what students have learned in class IX and the lecture method to trace the events. The students have read about the atom and its structure (Thomson model, Rutherford model, and Bohr model) in class IX, still, they have a number of alternative conceptions related to the atom and its structure. (Malhotra, 2020). The author used HPS approach to teach the chapter. The historical events starting from Democritus (early Greeks) to Bohr model were traced in the class. Videos available on the internet showing argument between Democritus and Aristotle, Lavoisier's experiment, and reconstruction of Rutherford's experiment were used as resource material. The lesson plan was designed using "The Story of Atomic Theory of Matter" by Joshi

& Sudhir and Nussbaum & Novick (1982) as reference material. The role of authority in science, philosophical debates, thought experiments, and the role of technology in advancement in the understanding of the structure of atom were highlighted during discussions in the class. Teaching of energy levels according to Bohr's model was done with help of a game. The game was a long jump game with lines drawn to represent energy levels in the hydrogen atom. Like the energy levels become closer as we move to higher levels, the gap between the lines kept decreasing with an increase in the level. The class was divided into groups with each group consisting of one student good at sports and one good with calculations. Each group had four members. The students represented electrons which had to jump from the ground state to different energy levels. Even if one electron is ionized the team wins. The electron could jump to a higher energy level only if the calculation for the energy required was done correctly by the team. The game helped students to understand energy levels and ionization energy.

The teaching-learning process involved history and philosophy of science, science, mathematics and the long-jump game.

Like these two examples cited by the author, some of the chapters are now taught using a STEAM. It was learnt from the experiment that a lot of effort is required for planning the lesson but integrating science with mathematics, technology and arts is possible at the senior school level too.

CONCLUSIONS

The author is a practicing teacher. Like all teachers teaching grades XI and XII, they were skeptical about using STEAM in the classroom. The lesson planning was very time-consuming but the two examples show that an integrated approach is possible even while teaching chemistry at the senior school level.

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LEARNING WITH ALGODOO: SIMULATION BUILDING AS A PEDAGOGICAL TOOL

Prathik Cherian J

Dept. of Physics, Prayoga Institute of Education Research, Bengaluru, India

he/him/his

prathik@prayoga.org.in

We describe an online learning project implemented using Algodoo - a free and easy-to-use 2-dimensional physics simulation building software - to teach students about certain physical phenomena in mechanics and optics. Our approach incorporated ideas of flipped learning pedagogy and was also based on constructivist principles of knowledge creation and sought to elicit conceptual change in students regarding specific physical phenomena in mechanics and optics. Students from an alternative school in Bengaluru, India were tasked with building their own animated simulations in Algodoo to explore physical phenomena of which they had no prior formal knowledge. The physical phenomena explored were 2-dimensional projectile motion from mechanics and total internal reflection from optics. The student responses suggest that with the right scaffolding, simulation building can be an effective pedagogical tool in science instruction especially in the context of an online educational setting.

INTRODUCTION

The global disruption due to COVID-19 did not spare the field of education. As lockdowns were announced, schools and universities had to shut down with classes and even labs moving to the online/virtual medium. As online classes became more and more common during the lockdown, within a short span of time, video conferencing software such as Zoom, Skype, Google Meet etc. became ubiquitous in many of our households even in India.

This represented an opportunity for us to attempt something novel. We set out to investigate the effectiveness of teaching in an online setting using simulation building as a core pedagogical tool. High quality simulations have been argued to be effective educational tools in enhancing students' conceptual understanding of various science topics at school level as well as college level (Finkelstein et al, 2006; Wieman et al., 2008). Our initiative involved using simulation building as part of an online instruction strategy. The ideas of flipped learning pedagogy (Kettle, 2013; Anand, 2021) were utilized in our project - students did the bulk of the work individually using the suggested reading material and videos and the facilitator interaction was limited to discussions of the work done and for clearing doubts.

In the next section, we explain the methodology of our project and its implementation in detail. In the subsequent and final section, we draw our conclusions.

METHODOLOGY AND IMPLEMENTATION

Students form certain alternate conceptions in a bid to explain their observations of the world (Driver, 1989). There has been a great deal of research into instructional strategies and how they deal with student preconceptions (van Heuvelen, 1991; Gurel et al., 2015). For an instructional strategy to be effective, first it has to address the student preconceptions and misconceptions, then create a cognitive conflict such that they are forced to re-evaluate, paving way for conceptual change (Posner, 1982).

We implemented an online project in physics for students in an alternative school in Bengaluru, India. We were looking to productively engage the students academically without the constraints of syllabus or curriculum and to elicit conceptual change. The duration of the project was 8 weeks during the COVID lockdown and 16 middle school students in the mixed-age grouping of 12-14 years took part in it.

The main thrust of the project was for students to explore hitherto unknown physical phenomena and try to gain insights through Algodoo simulations that they themselves build. Algodoo is a free software that lets users create interactive 2D physics simulations without needing any programming knowledge. The ease of use and overall design of Algodoo motivates and encourages student creativity (Gregorcic & Bodin, 2017). It is built on the principles of constructivism to enable users to construct knowledge by building simulations. Algodoo is especially useful for building physics simulations related to mechanics and optics.

By focusing on 2-dimensional projectile motion from mechanics and total internal reflection from optics, students would be forced to confront certain misconceptions regarding these phenomena. Several student misconceptions have been identified in geometrical optics specifically refraction (Kaewkhong et al., 2009). In the case of projectile motion, simulations have been seen to be effective in addressing misconceptions (Dilber et al., 2009).

The project consisted of two stages - an initial introductory stage of three weeks when students familiarized themselves with Algodoo, and the latter stage of five weeks when the physical phenomena were studied. It is worth pointing out that there were challenges related to working with a mixed age group of students due to their non-uniform intellectual and mathematical capabilities. Therefore, in the second stage of the project, the students were split into two groups - group A (consisting of 9 students) and group B (7 students). We now had a more uniform distribution of students in terms of their age, intellectual and mathematical capabilities within each of these groups. The assignments for each group were designed accordingly. The students were to submit their simulations along with the answers to the questions which were given to them at the beginning of the assignment. These questions were intended to probe as well as reinforce the conceptual change and understanding gained by the students through their experience with Algodoo.

During the entire duration, weekly interaction session with the facilitator was held via Zoom (60-90 minutes per session). During these sessions, students were to report their progress, and encouraged to clear doubts through discussions. I was loosely based on the flipped classroom pedagogy where the emphasis is on student's self-learning outside of classroom with materials provided by the facilitator (including videos as well as other web resources), and then having interactive discussions in class (typically, in person). It has been seen in different educational contexts that the flipped classroom method is more effective than the traditional pedagogical methods (Gilboy et al., 2015; DeLozier & Rhodes, 2016; Akçayır & Akçayır, 2018; Barral et al., 2018).

Simulating Contraptions

The first stage of the project required the students to build a simulation of a Rube-Goldberg Machine ("Rube Goldberg Machine", 2021). This assignment was conceived as an exercise for students to familiarise themselves with Algodoo and the functionalities it offers. Students were provided with links to youtube tutorial videos to learn the basics of the software.

Students had to simulate contraptions with a minimum of seven unique steps and submit the same at the end of three weeks. They also had to submit an explanation of the contraption mentioning the energy transfers occurring in each step. The students were provided with several youtube videos of complex Algodoo contraptions for inspiration, and given a free hand to design their contraptions.

The response of students was really encouraging. With some even getting so excited that they sent in trial simulations within the first week itself. With the aid of the online tutorials, students were able to come to grips with the software on their own. Some even had questions about employing programming scripts in Algodoo and one student in fact used some in his simulated contraption.

Most students (12/16) submitted their contraptions within the original deadline while the others required a further week's extension. A simple 4-point rubric was used to assess the simulations and the written submissions. It was seen that half the students scored well in both aspects whereas a few (4/16) did not submit the explanation about energy transfers involved in each step. Apart from simple mechanism like dominos and inclined planes, students were able to employ more interesting ones such as conveyor belts, pistons, helium objects etc. This implied that most students were successful in achieving the objective of familiarising themselves with Algodoo. Screenshot of a student submission is given in Figure 1.

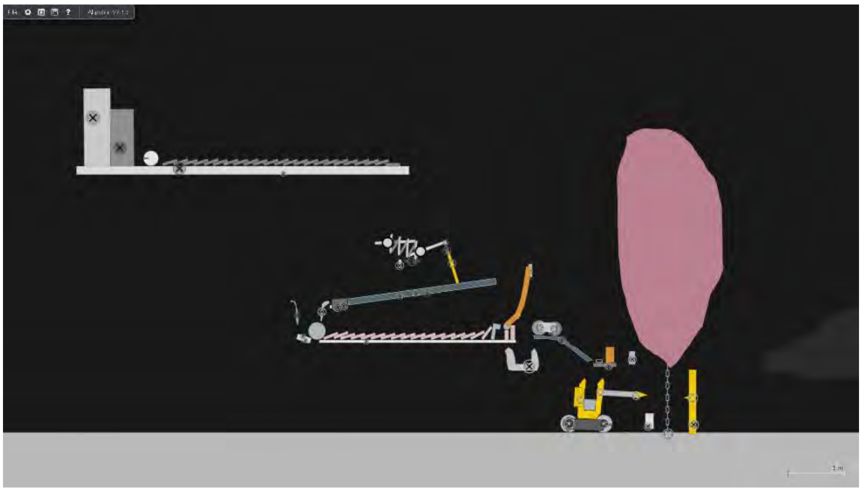

Figure 1: Simulation of contraption submitted by student CP.

Projectile Motion and Total Internal Reflection

In the second stage of the project, the students were split into two groups - group A (consisting of 9 students) and group B (7 students). Group A's assignment was to investigate 2-dimensional projectile motion while Group B's assignment was to investigate refraction and to discover the phenomenon of total internal reflection.

2-dimensional Projectile Motion (2dPM): The primary objective of the assignment for group A was to qualitatively study the relationship between different physical quantities in a 2dPM scenario such as the angle of projection, velocity, maximum height, range etc. Students were expected to create a simulation of 2dPM, collect the necessary data (by employing the plotting tool in Algodoo) and then analyse this data.

Apart from needing to recognise *what* data to collect, the key to a correct analysis was recognising the fact that data should be collected keeping the velocity constant. It was expected that students would identify that unlike the maximum height, the range did not necessarily increase with an increase in angle of projection. It was also hoped that by varying the angle of projection (in steps of 15 degrees), they would be able to identify that range would be maximum for an angle of projection of 45 degrees. Almost all the students (8/9) were able to realize that the maximum range was achieved when the angle of projection was 45 degrees.

Students were also given an open-ended question of looking into how the situation changes when air resistance is present (which is an option in Algodoo). The idea was that students could compare data and graphs between this situation and the previous situation, and come to their respective conclusions. Namely, that the range and maximum height reduces with the introduction of air resistance.

It was emphasised to the students that the focus was more on the analysis aspect and to treat Algodoo as a virtual lab to conduct experiments to collect data. One student submission of 2dPM simulation is given in Figure 2.

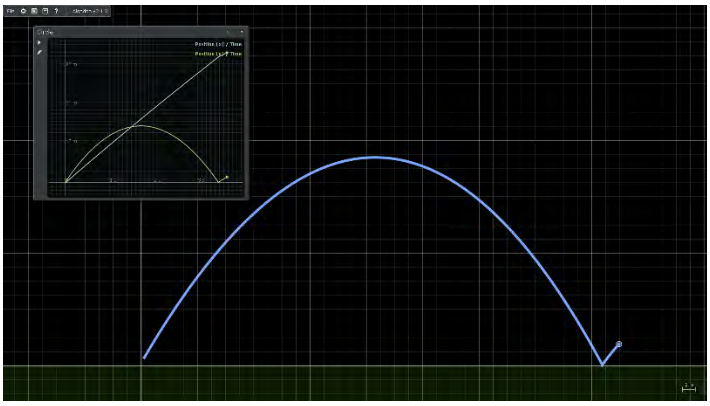

Figure 2: 2dPM simulation submitted by student AS.

From the submissions, it was clear that majority students understood the spirit of the assignment even if they were unable to do justice to it entirely. Even though most (8/9) were able to collect the relevant data, a considerable fraction of students (5/9) submitted poor or no analysis of the data. They did not seem to have sufficiently engaged with it. Students were able to identify how the energy changes occurred by studying the kinetic energy and potential energy plots and correlate it with the projectile motion.

Given that students had only studied motion in 1d, and had no prior formal knowledge of 2dPM, this was bound to be a challenging assignment that would require higher order thinking skills. Effort was made by the facilitator to ensure that students did not feel completely stranded. This was done through student driven discussions during the weekly Zoom sessions. For example, students were encouraged to identify the data they should collect through leading questions and to convince themselves (and each other) of the same.

Total Internal Reflection (TIR): The assignment given to group B consisted of two tasks. First task was for students to simulate dispersion through a prism. The main task was about discovering the phenomenon of total internal reflection. This was possible as Algodoo enables the manipulation of refractive index of any object created. The tasks were accompanied by questions that the students had to answer by using the respective simulations.

Almost all students (6/7) succeeded in simulating dispersion of light by a prism. But when they were posed the question of why this phenomenon occurred, the students were not able to come to the right explanation (i.e. the varying refractive indices of different coloured lights) even though they were able to make the observation that different coloured lights refracted differently. A screenshot of student submission for dispersion is shown in Figure 3.

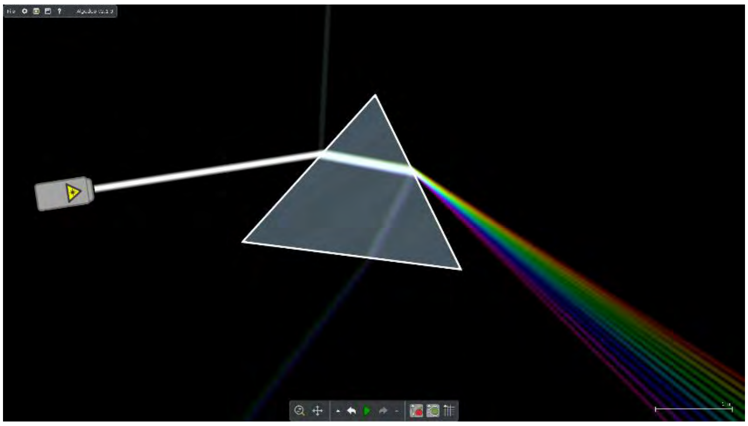

Figure 3: Simulation of dispersion submitted by student SK.

The final task was to introduce the concept of total internal reflection (TIR) to the students. It is important to stress that the students had no prior knowledge of TIR but did know about refraction. The expectation was for them to discover the phenomenon through the simulation. They were asked to create a simulation with two blocks stacked on top of each other. They were to then pass a laser beam through these blocks at different angles from the bottom and note down any strange observations - namely, the occurrence of TIR. They were also asked to reverse the order of the blocks and repeat the process and identify any differences - namely that TIR does not take place when light travels from rarer to denser medium. Further, students were also asked to create a bent optical fiber and to pass light into it through one end and check whether it was possible for the light ray to come out the other end. This was an exercise to recognize a real-life application of TIR. A screenshot of TIR fiber submission is shown in Figure 4 below.

Only 2/7 students were able to observe TIR in this task. They did not persevere enough with their simulations and felt that there was no difference between refraction through two blocks or single block. An explanation for this could be students' impatience and tendency to jump to conclusions given that they are working in a virtual medium and on their own. Some of the student answers pointed to a misconception that the observation would not be dissimilar to the case of a refraction through a single glass block which they knew about. Such a preconception would have stopped students from properly exploring the scenario with two glass blocks. But more students (4/7) did manage to observe TIR in optical fiber.

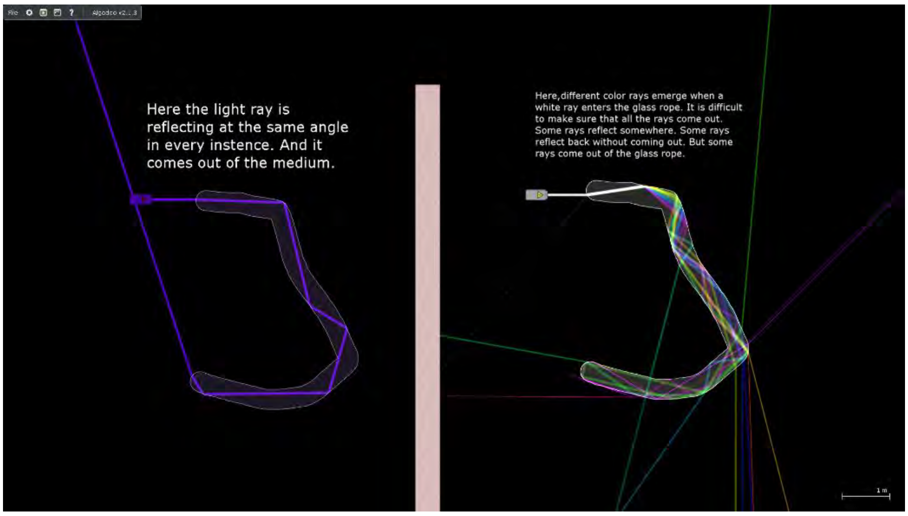

Figure 4: Optical fiber simulation submitted by student VK.

CONCLUSIONS

In this project, we attempted to elicit conceptual change in students regarding the topics of 2-dimensional projectile motion and total internal reflection through simulation building in Algodoo. The results were admittedly mixed. The nature of challenge in trying to necessitate a conceptual change became even more so due to the fact that we were attempting to do it via a non-traditional, online instructional strategy loosely modelled on flipped classroom pedagogy.

Some of the major challenges during the implementation were in terms of keeping the students engaged and maintaining their motivation. Even though these are not challenges exclusive to online instruction, they are arguably more difficult in a virtual setting. These aspects were in fact kept in mind while designing the project. But we are now forced to re-evaluate several aspects of our project. For example, the scaffolding attempted in this project has turned out to be somewhat insufficient. A lot more thought needs to be put into how it can be effectively implemented in an online setting.

On the flipside, simulation building could be very effective as a pedagogical tool in an experiential classroom as a strong alternative for the situations which are very difficult or impossible to create in a class/lab environment such as being able to manipulate air friction, gravitational acceleration etc (Coramik, 2021).

Maintaining student motivation was in particular a significant challenge. A couple of students in particular were not putting in enough effort and/or were disinterested as they were skipping the online interaction sessions, and having late or no submissions at all. Even though attempts were made to get through to them through individual cajoling, it was to no avail.

When designing such a project, we had considered the challenge of transitioning from hands-on activities to virtual experiments, and how it would impact the students' engagement with the subject content. Based on student feedback, it was clear that students found it difficult to maintain engagement in the virtual space. We had assumed that the novelty of building simulations would be sufficient to sustain students' motivation throughout the duration of the project. We had also hoped that discovering or learning about new physical phenomena through this medium would really excite and engage students. In hindsight, that seems too naive, and we have to identify richer strategies to keep students engaged and motivated.

Hence, a claim of success for our attempt would be disingenuous, but it certainly showed enough signs to warrant further study and consideration. Ultimately, the teacher proposes and the student disposes, and this especially rings true in the case of online instruction.

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MATHEMATICS FOR ALL AND EVERYONE'S MATHEMATICS

Pradnya Kadam

she/her/hers

Pradnyak710@gmail.com

To achieve a goal of "Mathematics for All" NEP (2020) and "Teaching for Construction of knowledge" NCF (2005), NCF (2005) has suggested to plan teaching and learning processes in the classroom in such a way that they correspond to the diverse needs of schools and explore positive strategies for providing education to all children. Therefore, in mathematics classes teachers are trying to use group activities, co-operative / collaborative methods of teaching. When such methods are used in the classroom various constructs such as power, authority, identity, autonomy, status, and positioning come into play. This summary is an attempt to understand dynamic relation between these constructs. Through this I wish to convey that along with all these constructs present in a learning space; presence of norms, rules and expectations of an activity and their right implementation without disturbing shared authority, autonomy with students play a very important role in achieving above mentioned both the goals.

INTRODUCTION

> Education is the single greatest tool for achieving social justice and equity. Inclusive and equitable education – while indeed an essential goal in its own right – is also critical to achieving an inclusive and equitable society in which every citizen has the opportunity to dream, thrive and contribute to the nation. (NEP, 2020, p.24)

NCF (2005, p.17), "Teaching and learning processes in the classroom should be planned to respond to the diverse needs of the students. Teachers can explore positive strategies for providing education to all children, including those perceived as having disabilities." For this NCF (2005) values interaction of students with the environment around, nature, things and people through actions and through language. And hence recommends students active engagement in enquiry, exploration, questioning, debates, application and reflection leading to theory building and create ideas, positions. For this it suggests assigning complex task in group situations or using collaborative learning, cooperative learning in the class. In these methods of learning students generate their own knowledge. I call this knowledge of mathematics which is constructed by students as "Everyone's Mathematics".

Hence NEP (2020) and NCF (2005) together have set two goals of achievement i.e "Mathematics for All" and "Everyone's Mathematics" in a mathematics classroom. Therefore, in this literature review, I am describing how these goals are achieved in classrooms. For that purpose, I have selected a subset of literature that talks about bringing equity in classroom and construction of ideas in classroom. But there is a problem of severe lack of such studies in Indian context. Hence I have selected literature that is situated in U.S American classrooms, where mathematics education committee has been publishing on precisely how these two goals can be simultaneously addressed. Rather than going into review of many studies of such kind, I have preferred going into details of small number of studies so that micro level dynamics can be captured.

In the following paragraphs, I am trying to illustrate how in the class group activities, complex activities, collective and collaborative activities are carried out. And which aspects of these activities help in forming strong mathematical identities, in what conditions they are effective. Usually to understand these things researchers have mainly considered interactions between student/s – student/s (Bishop, 2012; Langer-Osuna, 2016). They have talked about a role of a teacher during these activities (Ball, 1993; Horn, 2008; Wood 2013; Yackel et al., 1999), but effect of teacher's this significant role has not been analysed. In this summary, my attempt is to illustrate this role. This role of a teacher is very significant because it can channelize relationships present between all the constructs in an interactional space in such a way that it can either lead to achievement of equity in learning space and generation of students own knowledge or it can deny access of learning to some students.

When group activities, group discussions or classroom discussions are conducted in a class, constructs such as power, authority, identity, agency, figured worlds, positioning, competency, autonomy and status come into play. All these constructs are related to each other and have very significant impact on learning.

Most of the time teachers select mathematics problems which have many strategies of solving or multiple solutions (Ball, 1993; Yackel et al., 1991), so that it can help initiation of group discussion. By doing this, teachers try to use mathematical processes, which are followed by community of mathematicians (Ball, 1993; Dunleavy, 2015; Horn, 2008). Because authority is shared among students they can select, negotiate their role in group activity according to power (social and academic) they possess (Ball, 1993; Horn, 2008; Langer-Osuna, 2015).

Based on presence and absence of norms and rules for conduction of these activities (set by the teacher or class as a whole), which are stated directly or indirectly by the teacher relationship between the constructs has been discussed in detail in the following two main sections.

POWER, AUTHORITY, AND ABSENCE OF NORMS AND EXPECTATIONS OF PARTICIPATION

Classroom is a social context in which a teacher conducts a group activities or discussions. The teacher and all students are participants of this activity. All these participants come from various backgrounds for example: social, economic, racial, color. Therefore from their different backgrounds they bring various different experiences and different interpretations of their social and home world to the class. These experiences and interpretations made by students control students' classroom interactions, participation and reactions (Esmonde & Langer –Osuna, 2013, Langer-Osuna, 2015). Students who come from high socio-economical background or from high class hold social power (Langer-Osuna, 2016), which becomes visible in their smartness. Their smartness helps them in gaining social authority in classroom interactions (Esmonde &Langer-Osuna, 2013; Langer-Osuna, 2015; 2016). With gained social authority they can control or hinder other participants' development in subject (Langer-Osuna, 2016).

Power and Authority Affects Positioning

If in group activities a teacher does not set norms and expectations for conduction of the activity then social power and hence gained authority together helps a student to place himself/ herself at higher status and there by contribute agency in learning, at the same time it discourages others from advancing in learning and positions them as help seekers (dependents) and there by hinders their growth.

Langer-Osuna (2016) was looking for relationships of authority that children develop when they interactionally position themselves and one another with academic and social power while working in small group collaborative mathematics problem solving in elementary classroom

Ana (who was smart in conveying her socially accepted behavior to the teacher) advanced teacher's acceptance for her answers even though her answers did not contribute to the solution of the problem. Whereas Jerome (who was not enough smart) exhibited socially unacceptable (off task) behavior in the beginning of the group activity, he got instructions from the teacher that he should work with Ana in the activity. Because of this kind of influence of Jerome on the teacher, he failed to achieve her attention on drawing of correct diagram of the problem. This increased Ana's confidence and for whole of the session she gave directives to Jerome. He accepted all her directives without any rejection. Thus social power and authority that Ana gained indirectly from her teacher, and Jerome lost because of non-acceptance by the teacher had lots of impact on their participation in the activity. The teacher did not point at other students in the class who were off task and only directed Jerome. One of the reasons for the teacher's this behavior could be merit of perceived behavior of students in the class (Langer-Osuna, 2016).

Similarly, Langer-Osuna (2015) was investigating the co-construction of student identity in 9th grade, project based algebra classroom, where students were given great deal of autonomy. Terrence a student from the class was a tough guy. He did not mind smoking while walking to the school. Also he was getting involved into fights with neighbors. Because of his this background and his interpretation of his social and home world made him to work at periphery in the first project work of the academic year. In contrast, Brianna, who was able to show her smartness gains project manager post for the project and hence she gains academic and social authority, she used it in directing the group members for their project related to work. Her post allowed her to take Terrence negligence towards project work to their teacher for serious action.

If group activities are not managed by any norms and rules then because of good mathematical competence and smartness the students who gain more academic and social authority, position themselves at the core of an activity in group work (Bishop, 2012; Langer-Osuna, 2015, 2016; Turner et al., 2013). They contribute to the task comparatively more than others. Esmonde (2009) in his a yearlong study in secondary classes compared 2 activity structures – a group quiz and a presentation. He found that in both the group activities viz. group quiz and presentation preparation, students who were mathematically competent always contributed more than others. In all the work practices except (Individual working groups with no expert and no facilitator) strategies for solving the problems given by experts were always accepted by others without any demand of justification or questioning back. Experts only showed steps of solving a problem or at times only gave direct solution of problems to other students. They never gave any explanation of their solving. Also novices never asked for reasons. This is how with gained academic authority expert students achieved social power also. With academic and social power they controlled other students learning. Thus moment to moment positioning of students in a group by themselves and by others as experts or novices etc. decides their identity as problem solver or menial worker in a class (Wood, 2013). Here in both kinds of group activities the teacher intervened only when students asked for help or at the time of evaluation of activities. Expert student were not given any practice of explanation of solutions, reasoning, and about how to help academically poor students.

Positioning Affect Status and Identity

On similar line, Bishop (2012) in his study with a middle school mathematics classroom found that while working in pairs on a problem solving activity Teri (a student who was considered as smart and mathematical competent) always positioned herself as an expert student and Bonnie (who was mathematically less competent) was positioned by Teri as dumb. Because Teri got smart status she always appropriated position of power. While solving problem together, even though at some places Bonnie tried to understand pattern in the solution of the problem, she conjectured about the pattern and also suggested some values for solution; Teri never took up her ideas or continued discussion on topics which Bonnie initiated. Instead when she observed same pattern in solution she celebrated it as her finding. Bonnie was never given credit for her contribution in pair work. Teri exercised her authority over Bonnie in every aspect of problem solving. Hence Bonnie could never uplift her status and remained identified as unknowledgeable or dumb.

From all the above accounts it is clear that even though teachers choose to conduct group activities (but do not set any norms or rules for doing the activity or working in group); and they try to create learning spaces where with shared authority and autonomy of learning students are able to choose and negotiate their role in a group activity but in reality students do not get placed at equal status. They position themselves and others as different identities. Students who position themselves and get positioned by others as novices, help seekers, dependent students develop poor mathematical identities (Esmonde, 2009; Wood, 2013). Even though autonomy and authority in learning is given to them also, because of lack of power and the way they get positioned in an interactional space (by expert students) these students fail to attain equal opportunities of learning. Therefore they remain marginalized, eventually as the cycle continues they become more and more relegated and form very weak identities. In a class students who remain marginalized because of some reason find it difficult to break this cycle (Langer-Osuna, 2015, Wood, 2013). Hence goal of “Mathematics for All” and “Everyone’s Mathematics” is not attained in such cases. Therefore, a question arises that what can be done in such situations.

POWER, AUTHORITY AND PRESENCE OF NORMS AND EXPECTATIONS OF PARTICIPATION

It is possible that a teacher pays close attention to how students get positioned at every moment along with distribution of authority and autonomy of learning in a class (Ball, 1993; Horn, 2008; Langer-Osuna, 2015; Turner et al., 2013; Yackel et al. 1991, 1999). This role of a teacher does not need much facilitation in actual mathematics problem solving. What she needs to do is to form or have some norms and expectations about implementation of those norms in a group activity. Sometimes they need to be explicitly stated and some other time they can be incorporated in the activity itself.

Authority Affects Positioning, Agency, Competence and Identity

Langer- Osuna (2015) found that Mr. Steven (the teacher) was following professional high tech industrial culture in his class. Hence rules for students conduct, behavior and working were adopted from that culture. And authority was distributed to the students of his class. Students had to choose a role for themselves in the group project work. Terrance for the first project of the year remained at periphery and did not contribute much towards completion of the project work. According to culture adapted to the class, students in the group had right to ‘fire’ someone from the project work if he/she was not performing his role or duties according to work distribution. This authority the teacher did not keep with himself but it was distributed among all the group members. Hence when the group decided to take such an action against Terrance and brought the matter to Mr. Steven, he tried to give one more chance to Terrance. For this he asked Terrance to decide about some good steps forward. This is how the teacher positioned the student as an agentive member who could negotiate his role in the project. Terrance's autonomy of choosing role in the activity was preserved by the teacher. But at the same time he had to negotiate his role with other group members. By doing this the teacher did not disturb distributed authority among the group members towards completion of the project. This way Mr. Steven gave a chance to Terrance to reconcile his positional identity in the group. Towards end of the year Terrance was found more responsible. He thought about pulling his grades up. For that he started asking for reasons and justification for solutions of the problems to other expert students who were helping him in the project work. Thus by applying norms and rules for positioning students appropriately in collective work the teacher provided opportunity to reconcile academic identity and also helped him in developing right social identity.

Similarly, Horn (2008) analyzed a class session conducted by a researcher Deborah Ball (here the teacher of the class) on January 19, 1990. She found that in Ball's (the teacher) class authority of learning was delegated to students. By setting norms and expectations of behavior for accountable disagreement argumentation participants could position themselves and others in various roles such as: principal of controversy, dissenter, ally, questioner, listener, reasoner, clarifier and role maintainer in moment to moment interaction in the group disagreement episodes. While discussing the conjecture 'six is even or odd' the teacher did not interrupt much in question answer disagreement sequence. She played a role of norm maintainer. Along with norms, expectations and shared authority of learning students accepted responsibility of their roles. For example, to initiate discussion in the class the teacher asked for comments by others on Sean's conjecture. She asked Sean if he wanted to say anything. By doing this she positioned Sean as a 'principal of controversy', and initiated disagreement argumentation. Sean and other students were given chance to be agentive member of the learning space. Similarly, by asking Betsy to pay attention to what Sheena is saying she positioned Betsy in the role of 'listener'. In this way students adopted various roles along with norms and expectations about those roles during an accountable argumentation episode. Here they learnt mathematical processes and also reached to generalization of the conjecture 'six is even or odd'. This helped them to build mathematical competence. Here knowledge generated was their own knowledge. They were owner of the generated knowledge and students could develop mathematics related identity. Therefore, this teaching learning sequence not only achieved the aim of "Mathematics for All" but also "Everyone's Mathematics".

On a similar line, Gresalfi (2008) was interested in investigating how individual competence can get constructed through individual participation in an activity system such as classroom. To build competence among students and hence help every child to come up with his/ her own explanation of decisions taken for solving the problem and to help children to build their own understanding of concept, the teacher had set some norms of participation in class. According to these norms students were accountable for explaining their all decisions related to the activity to the teacher and other students of her class. Students were considered as authority figures in doing mathematics. Hence when Callie approached the teacher with a doubt in James paper, the teacher did not clarify his doubt on herself. Instead she involved James in the discussion of doubts. And she asked James to explain his choice of symbols. James agreed that his symbols lack in clarity and he should assign more meaningful symbols. Here, the teacher could evaluate Callie and James as lacking mathematical competence in understanding the activity. In contrast, she positioned both of them in agentive role. James had to think conceptually to come up with meaningful symbols. In this way both the students got a chance to improve their mathematical competence and their mathematical identity was ratified.

Positioning Affects Agency, Competence, Identity and Hence on Attaining Equity

Yackel et al. (1998) to illustrate how mathematical meaning is interactively constructed in the classroom analyzed one second grade classroom. The teacher in the class had aim to help students to build their own understanding of horizontal addition and subtraction number sentence problem. Hence he wanted students to have their own mathematics i.e. “Everyone’s Mathematics”. This teacher accidently invented a pedagogical move, asking for different solutions by asking “anything different”, in his initial classes on horizontal addition and subtraction of two numbers. Later on he made a rule for the class that every time whenever students tell any strategy for finding the sum of the two numbers (same number sentence), it should be different from the strategies discussed earlier in the class. And students also had to tell the teacher and the whole class that why and how his/ her solution was different. Hence, whenever students told a solution they had to think about different ways of decomposing the numbers (in tens and units), and different ways of rearranging and combining them. At the same time they also had to compare their present way of combining with earlier ways of solving the same problem. To meet with teacher’s demands of answering solution the students had to use conceptual agency. By implementing this kind of rule in his pedagogy of teaching the teacher positioned each child of the class as a mathematically competent member of the class. Knowledge constructed by the students in this process was their own knowledge. Hence the teacher’s norm which he formed to position each students as agentive member where they had to think conceptually helped the students to generate their own knowledge. Hence the teacher could achieve both the goals i.e. “Mathematics for All” and “Everyone’s Mathematics”.

In some classes even though the teacher sets norms for conducting activity in the class, and he/she delegates authority of learning to the students, the teacher finds hard to accomplish equity in her classroom. If students of the class come from socially marginalized groups then their social status prevents them from active participation in group activity. Turner et al., (2013) studied about the discursive positioning moves which can facilitate Latino/a English learners’ agentive roles in group mathematical discussion. They found that the teacher’s norms about using English as well as Spanish in the class for classroom discussion, about encouraging EL’s to communicate with multiple resources (including their home language), about allowing students to revoice each other’s’ explanations in their dominant language positioned students in agentive role. Thereby she tried to achieve equity in the class.

Delegated Authority can Create Dilemmas in Learning Space and Have Effect on Identity

The teacher’s practices for of delegating mathematical authority include positioning all students to offer mathematically meaningful contributions and cultivating a classroom community in which all students are given opportunities to display answer (Dunleavy, 2015). But this situation can put a teacher in dilemma. Ball (1993) analyzed her own classes that were organized around authentic tasks in elementary school mathematics class. Here students were given autonomy of learning by allowing them to conjecture, to experiment and to make arguments. The researcher has presented her own dilemmas that she faced during these classes. She found that while allowing students to work with the problem at hand till everyone’s consensus the teacher may face with the dilemma of creating and using mathematical community. The teacher become puzzled that how long the discussion of the same problem should be allowed. At what points students should be told the correct and final answer. They should be given hints or not even though they reach very near to the solution and hint can help them to get the answer immediately. Hence even though the teacher strives for ‘Mathematics for All’ and ‘Everyone’s Mathematics’ taking in the moment decisions which can lead to attainment of these goals is hard.

Demand of Conceptual Agency for Attaining Equity

Even though for getting equity in the classroom teacher delegates authority of learning to the students to keep cognitive demands of the task at hand high the teacher poses students with questions which demand conceptual agency. For example Dunleavy (2015) was interested in exploring the pedagogical processes for delegating mathematical authority to students and by assigning tasks that require multiple abilities and multiple entry points. The teacher in the class created opportunities for equal – status interactions, thereby worked toward equity attainment. He found that in whole class discussion when the teacher called Naima to lead the class discussion, and when Naima wrote a conceptually challenging statement ‘needs to start @10’ on the board the teacher challenged her contribution by asking her to explain why the graph on Y-axis should start on 10. Similarly other students of the class challenged Naima. Naima gave explanation for her written sentence on the board.

Power and Authority Affects Positioning and hence Identity

Wood (2013) explored students’ participation in mathematics classroom in one fourth grade classroom. He used identity tool for understanding influence of minor change in context and positioning on a student in the moment micro identity. He found that Jakeel who was considered as mathematically struggling student could enact his micro identity as mathematical explainer only when teacher questioned him about his work and demanded for explanation for his solving. The teacher’s norm was, every child should explain his or her work and show how he or she has arrived at the solution. Whenever Jakeel was positioned as an explainer and his responses were scaffolded by the teacher. Jakeel took up the position of explainer, responded to each of the teacher’s question with his mathematical reasoning. While responding to the teacher he showed his eagerness with many of his actions. Jakeel’s explanations positioned him as an authority and source of mathematical ideas. Whereas when Jakeel worked in a group, that is, with Rabecca (mathematically expert student) he could not maintain his micro identity as a mathematical explainer. Rabecca was considered as a smart and intelligent student by her teacher and other students in the class. Hence Rabecca had social and academic power and authority. While discussing problem with Jakeel, Rabecca exercised her authority over Jakeel in many ways. In her discussion with Jakkeel she only focused on his physical activity, without giving explanation about why to do. She merely told him what to do, where to do and when to do. In this way instead of discussing problem with Jakeel she only gave directives to him and positioned him as menial worker.

From the above account it is clear that mere setting of norms does not work, teacher must attentively follow the group processes to see whether students really follow them or not. Cobb et al. (2009) propose an interpretive scheme that can analyze the characteristics of identities developed in mathematics classroom and that can inform the design of activities for the class. In doing so they found that class where students are obliged to explain their work to others, ask clarifying questions for the unclear part of the activity and demonstrated solution methods, work on analysis part of the data rather than collecting data, indicate and give reasons for disagreement with other student’s claims develop positive and strong mathematical identities, they most of the time use conceptual agency.

Norms and Expectations Affect Positioning, Conceptual Agency and hence Identity

Yackel et. al., (1991) were looking for construction of classroom norms for cooperation and on the learning opportunities that arise in the course of interactions when children work in small groups to complete mathematical activities in a second grade mathematics classroom. The teacher in the class found a solution for establishing norms in the class through teacher's specific behavior. To set norms in the class the teacher adopted unusual way. She initiated and guided mutual construction of norms. For example, in a group activity when she saw that one child was solving the given problem and was not showing it to other students of the group even though they needed help, she reached the group and guided the children for asking help in clear words. She guided them to tell the partner in clear words, "I don't understand this." She made them clear that if all the students in the group would not give me correct solution then the child who did not help would be in a trouble. After the activity finished, she again initiated whole class discussion on this. And asked the group to narrate non- cooperative incident happened in their group. Most of the time before starting the activity, the teacher initiated discussion on cooperative behavior in the group. When children are trained in this way for cooperative group behavior then their behavior retains for a long time (Gillies, 2000). Even if these children are placed in different group they exhibit similar cooperative behavior. Not only this have had they used higher level of cognitive strategies for helping others, such as giving reasons and specific concrete relations (Gillies, 2000).

Refutation of Norms and Expectations by Students

It is not always the case that the teacher sets the classroom norms and expert students always refuse to follow them. Sometimes expert students try to give constructive help to help seekers but help seekers or less competent students deny their help in constructive form. For example, Esmonde and Langer- Osuna (2013) investigated that in culturally and racially heterogeneous group students used resources provided by mathematical figured world to position them powerfully. Although the teacher of the class had laid norms of cooperative behavior in the class students' behavior was not aligned with those norms. In teacher's absence whenever an expert student Riley (White American boy) tried to take attention of Dawn (African American girl, help seeker) in activity by asking her question Dawn's response did not align with it, she turned his question back to him. Sometimes she showed her opposition by changing tone or body positioning. Riley's moves were considered as power exercising on them. Nature of interaction between Riley and Dawn were always direct style. Dawn wanted Riley to answer only her questions directly without giving any explanation or asking any question back to her. This was result of presence of racial and gendered differences present in the group. Whereas, when Dawn came up with different answer than Riley, she initiated mathematical discussions with him. In such instances the type of discussion was different, Dawn challenged Riley for his value, conjectured about a possible value, got her ideas clarified, made Riley to change his contributions. Thus in higher classes when student's social identity has been form then that identity might make them to behave against the teacher and other expert students. But at the same time this identity can help them to position themselves with respect to main stream part of the society confidently and will help them to get help from them to develop their academic identity.

Hence along with authority delegation if a teacher also uses norms and rules at right place to position child in such a way that the child gets agency for his learning in the class and he/ she is placed with respect to others perspective at responsible position then the child develops sense of mathematical competence and hence forms positive mathematical identity. Thereby it is possible to attain both the gaols of "Mathematics for All" and "Everyone's Mathematics"

I have tried to capture all the above discussion about dynamic relationship between all the constructs which are present in learning space in the form of diagram.

The following figure shows relationship of constructs present in an interactional space of a group activity, whole class discussions or group discussions.

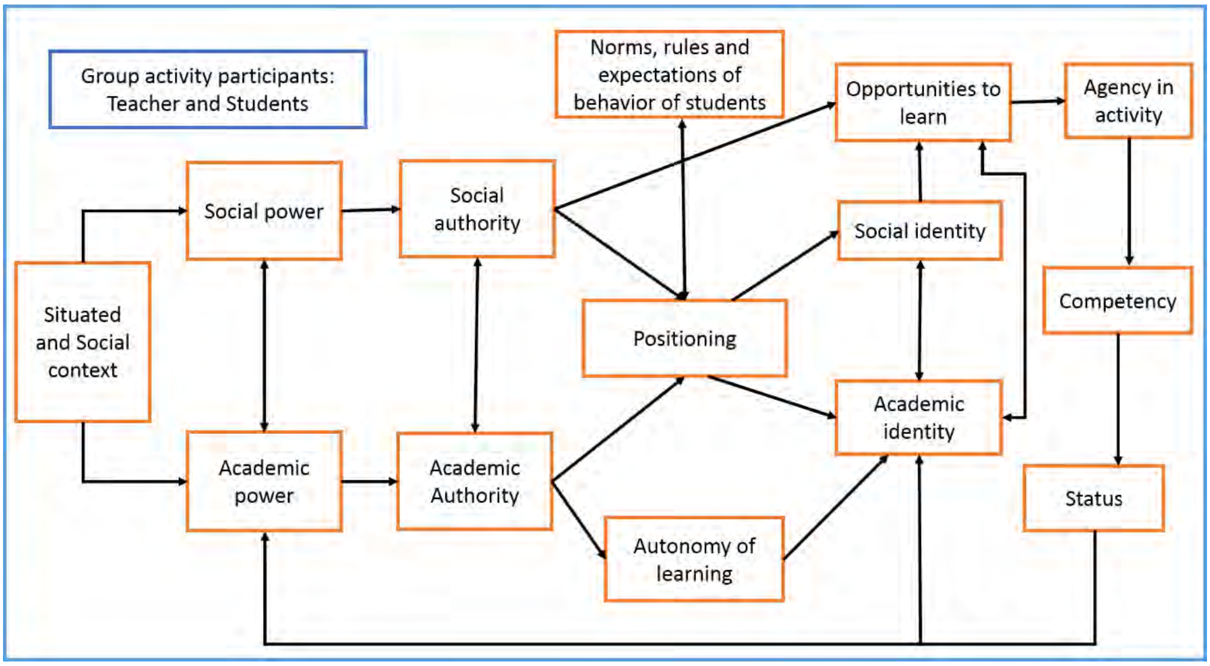

Figure 1: Relationship of Constructs Present in a Learning Space of a Group Activity

In the above figure, from the paragraphs discussed in the beginning of discussion of this paper, the first main part contribute in the form of effect of power, authority on positioning and formation of both the kind of identities i.e. social and academic identities. Then from the same part of the discussion effect of positioning on status and identity formation contributes further when no norms and rules for conduction of activity are present in the learning space. Similarly in the above figure, the second main part of the discussion of the paper contributes when teacher leads norms and rules along with expectations from activity conduction. This part contributes how authority helps in positioning as agency and reconciling social and academic identities. This part also contributes on effect of authority on positioning and formation of identity. And hence gaining mathematical competence in terms of conceptual agency. Hence the child gains higher status in the class and thus his/ her academic power increases and impacts social power and cycle goes on. This helps in achieving equity in the learning space. In fact all the constructs are present in all the learning space and based on teacher's role they get related to each other. Some of the ways have been captured in papers discussed in this review paper.

CONCLUDING THOUGHTS

From all the above accounts it is clear that mere sharing of authority of learning among students equity of learning cannot be accomplished. Because only shared authority does not put everyone in the group at same status. To have equity of learning in a classroom it is required that everyone in a group is placed at equal status and they form right identities of learning. Only student/s –

student/s interaction does not place all the students at equal status. Teacher –student/s interaction also act as an important aspects of collaborative learning. With slight interference in group activity to set norms, expectations and executing those norms at right time the teacher can make learning equitable. Hence a teacher can attain both the purposes of learning, ‘‘Mathematics for All” and “Everyone’s Mathematics”.

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STUDENTS' DIFFICULTY ON LEARNING GEOMETRY

Hasina Hakakzada[1], Ruchi S. Kumar[2]

[1]SCA, [2]Tata Institute of Social Sciences

[1]hasinahakakzada@gmail.com, [2]ruchi.kumar31@gmail.com

This research mainly aimed to identify the difficulties that students face in geometry learning. The research was done based on the theory originated by Dina van Hiele and Pierre van Hiele in 1957. According to the van Hiele theory, geometry learning happens thorough passing five levels in a sequenced way and students usually do not reach to higher levels of thinking that is cause of improper sequence in geometry materials. The study was done by choosing the geometrical shapes topic in grade 2 and a public secondary school in Kabul city (the capital of Afghanistan) was chosen for the process of data collection. Two classes were observed during the teaching of geometrical shapes and students were asked to take a paper test of identifying geometrical shapes. Additionally, both of the teachers of the specified classes were interviewed and the geometry chapter including the introduction of geometrical shapes of Afghanistan and India were compared and analyzed. The study revealed that students were not able to identify geometrical shapes in different situations and representations- at van Hiele level 1 and they were not able to identify similarities and differences of the shapes hence they have not reached van Hiele level 2. Moreover, the second grade textbook of Afghanistan included only counting and identifying stereotypical shapes whereas Indian textbook activity of comparing similarities and differences between shapes can help student move to level 2.

INTRODUCTION

The geometry learning and teaching is one of the issues that have been favorite topics for researchers to investigate over decades. Since, still it requires more work to provide the better learning opportunities of geometry for students and understanding of how students learn geometry for teachers.

Research on students' learning of geometry has addressed the complexity and difficulty in learning school geometry at all levels. As well as, other educational and psychological concerns (Wang, 2016). The Van Hiele theory was developed by two mathematics teachers from Holland in late 1950's. The theory has been applied to explain the students' difficulty in higher order cognitive processes. Moreover, it suggests the solution for how children learn geometry, by representing five levels. The base level (level 0), children use to judge figures by their appearance, the usage of visual perception and nonverbal thinking is usual in this level. At second level (analysis) pupils cannot differ necessary and sufficient properties of shapes or, a geometric figure is bearer of its properties as students use to recognize figures by their properties. At the next level (abstraction), students perceive relationship between properties and shapes as the properties of figures are ordered in this level. In the third level (deduction), students use to give deductive geometric proofs, differentiate between necessary and sufficient conditions and understand the role of definitions, theorems, axioms and proofs, and in the final level (rigor) , students are capable of analyzing and compare various deductive systems (van Hiele, 1985). A considerable amount of research has established van Hiele theory as a generally accurate description of the development of students' geometric thinking (Clements & Battista, 1992).

Students pass through each level step by step. Moreover, the theory has three aspects, namely, the existence of levels, the properties of the levels, and the progress from one level to the next level. The levels have five characteristics; fixed sequence that emphasize on passing of students from each level in order. Adjacency, which shows that each preceding task in previous level becomes extrinsic in current level. Distinction, represents that each level has its own linguistic symbols and network of relationships that connect them. Separation, shows that two individuals at different levels cannot understand each other (Vojkuvkova, 2012). Van Hiele believed that this property is one of the main reasons of failure in geometry. And the final property is attainment which implies that the learning process leading to complete understanding at the next level has five phases-information, guided to orientation, integration, which are absolutely sequential. According to Van Hieles, cognitive progress in geometry can be accelerated by instruction and progress from one level to other is more dependent to instruction than age or maturity. Also, they represented strong clarifications about how teacher must proceed to guide students from one level to the next. Traditional teaching methods often involve only Integration phase, which explains why students do not master the material. Teachers believe they express themselves clearly and logically, but their reasoning is not understandable to students at lower levels (Vojkuvkova, 2012).

METHODS

This research is a descriptive and comparative approach in order to identify students' difficulties in geometry. The sources of these difficulties is investigated in textbooks as well as students' thinking patterns. Therefore, a public secondary level school is chosen in Kabul city (capital of Afghanistan), the school was established in 1913 and had 1200 students, including boys and girls from grade 1 to 9 in two shifts and 53 teachers including 50 % bachelor and lower level of education degree during the data collection.

The textbooks are analyzed by doing comparative analysis of Indian and Afghan textbooks. Also, two second grade classes were chosen, the class 2 A included 30 students and 25 students were present during the test also class B included 32 students and 30 of them were present on the time test was given. Both classes were observed during teaching of geometrical shapes and students of both classes took a test of identifying different geometrical shapes. In addition, both teachers of the classes were interviewed. Table 1 represents the tools used in this investigation.

Tool	Purpose
Textbook analysis	Identifying the possible supporting points in learning geometry in second grade textbook. Identifying the obstacles in the second grade textbook that might affect students learning in geometry subject.
Observation	Identifying that how second grade teachers use to teach geometry in Afghan schools. Identifying the factors that may act as obstacles for learning geometry during the class.
Interview	Identifying whether second grade teachers have information about teaching geometry efficiently and what problems they face while teaching of geometry.

Test	What is the levels of students' understanding of geometrical figures without using any properties of the shapes during the test?

Table 1: Data Collection Tools

RESULT

The classroom observation revealed that both of the teachers did not use to rely on the textbook and the guidelines of the textbook and they try to enhance learning for students by using some materials and performing some tasks by the students. Moreover, it was observed that students were actively involved in the teaching learning process by engaging in different activities such as constructing shapes, drawing shapes and identifying shapes. Additionally, both countries' textbooks comparison shows a significant difference in introduction of geometric shapes for children that are shown in table 2.

Afghan 2nd grade mathematics textbook geometrical shapes chapter	**Indian 2nd grade mathematics textbook geometrical shapes chapter**
Is covered in 4 pages	Is included in 8 pages
Starts by Introduction of geometrical shapes.	Starts with a story about footprints (non-geometrical) shapes.
Includes 4 activities.	Includes 15 different activities.
The chapter starts by introducing the geometrical figures.	Previous chapter introduces the idea of patterns. This idea is built upon in the chapter on shapes. It is started by covering non geometrical shapes and then moving to geometrical shapes.
Covers the concepts of geometrical shapes and jumps to the concept of perimeter	The concepts of non-geometrical shapes and geometrical shapes are covered
Covers the activities of: • Naming given geometrical shapes • Identifying features of different shapes like corners, sides etc • Matching shapes with given words. • Counting number of geometrical shapes in a drawing having combination of shapes • Identifying geometrical shapes in the environment	Covers the activities of: • Matching, drawing and tracing non-geometrical shapes • Identifying shapes and features from different perspectives • Comparing similarities and differences. • Drawing missing parts of a picture • Drawing geometrical shapes • Sorting figures • Counting geometrical shapes • Make drawing by combining geometrical shapes
Properties of the shapes are described	Properties of the shapes are not described but

	students are expected to describe the shapes in their own words
Students have opportunity of comparing and identifying similarities between the different shapes in one activity	Students have different opportunities covered by variety of exercises to compare and identify similarities and differences between different shapes and their properties
Introduces the concepts by using limited number of words	Contains stories for the introducing the concepts
Includes stereotypical shapes	Includes variety of shapes
Contains only a few pictures	Illustrates variety of colorful figures and pictures

Table 2: Comparison of Afghan and Indian textbook

CONCLUSION

By analyzing each of the activities and practices covered in Indian textbook it can be concluded that the Indian textbook covers a careful approach in introducing geometrical figures for the students. And not only introduces them with geometrical shapes but also gives them the opportunity to compare and draw geometrical shapes as well as non-geometrical shapes by variety of practical activities and tasks. The data the data also represents that there are limited supporting points in the Afghanistan second grade mathematics textbooks that can be helpful for students to learn geometrical shapes in comparison of Indian textbook. For instance, they are being introduced with the properties of the shapes and this can help them to identify shapes by their properties also, there are some activities included that students can compare the similarities and differences of the shapes. As well as, the activity of identifying shapes in the environment and in the given figures that covers variety of the shapes. Correspondingly, there are lots of supporting points in the Indian second grade math textbook that can help students to understand geometrical shapes.

The Afghan textbook introduced the geometrical shapes directly whereas, Indian textbook first represents the chapter covering different non-geometrical patterns at first and then represents geometrical shapes in a way that students get the opportunity to compare the shapes and get introduced with the geometrical figures. In addition, Indian textbook covers interesting stories and pictures which can be interesting for students and guide to better understanding of the concepts. Moreover, there are other activities such as comparing and sorting figures and patterns which leads students to exploration and focus on the properties of the shapes. Also there were some obstacles in the textbook of Afghanistan which are considered important for students learning such as representing only stereotypical shapes in the textbook, no drawing activity for students and lack of activities for students to enable them in identifying shapes in various situations and representations. Additionally, the last part of the geometry chapter covers the concept of measurement as it covers parameter of the shapes and its measurement, this can act as obstacle for students.

The observation and interviews of the teachers also presented data that show the approach of second grade teachers in teaching geometry. The observation of the classes revealed that the more experienced teacher used to teach in a way that created better understanding of geometric shapes in students also the test of students showed that class 2 B students performed well in identifying geometric figures. Additionally, the data shows that however the teachers used different activities during the teaching of geometric shapes while the teachers' content knowledge is not adequate in geometry as one of the teachers gave the examples of 3d tools in order to learn 2d shapes and said "the tools at home such as radio, refrigerator, TV, wardrobe, dishes and other things around can help students to learn geometrical shapes" also, it was observed that one of the teachers used 3D models for teaching geometric shapes in 2D space. Additionally, during the interview one of the teachers mentioned that 70% learning happens through visual sense therefore, picture representation is more important for teaching and learning geometrical shapes and the teacher must give more visual example for the geometric figures whereas, this argument is not completely correct and there should be more activities for students to get encouraged in using their different senses and skills and make own schemas regarding to the geometric concepts. The most important barriers were representing stereotypical shapes by the teacher, using 3D shapes, and not giving enough opportunity of identifying variety of shapes for students to consider the shapes' differences and their properties.

The data collected through test also revealed that student were not able to to identify geometrical shapes in different situations and different representations- at van Hiele level 1 neither they are able to identify similarities and differences of the shapes. Hence, they have not reached van Hiele level 2. The second grade textbook of Afghanistan includes only counting and identifying stereotypical shapes while Indian textbook activity of comparing similarities and differences between shapes that assist students in moving to level 2. Moreover, teaching is also focused on identifying and counting shapes thus students focus only on stereotypical shape.

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STUDY OF DAMPED OSCILLATORY MOTION OF SPRING-MASS SYSTEM USING VIDEO ANALYSIS TECHNIQUE

Rajesh BM[1*], Shubha S[1#], Avadhani DN[1!], Satish BM[2$] and Madhura TK[3&]

[1]Department of Physics, R V College of Engineering, Bengaluru 560059, India

[2]Principal, Sree Vidyanikethan Engineering College, *Tirupati 517102, India*

3Department of Education, Mount Carmel College, Bengaluru 560052, India

[*]rajeshbm@rvce.edu.in, [#]shubhas@rvce.edu.in, [!]avadhanidn@rvce.edu.in,
[$]satishbhujangmutt@gmail.com, [&]madhura.tk@mccblr.edu.in

The present study demonstrates understanding of damped oscillatory motion in an interactive approach. The insights of the damped oscillations are provided by tracker video analysis tool. It is used to determine various physical parameters such as time period, amplitude, damping coefficient, damped angular frequency and quality factor. In order to obtain the solutions for the second order differential equation of damped harmonic oscillation, we make use of displacement - time curve as a teaching/learning aid. Results are graphically presented and the excellent curve fit observed for damped oscillations in water and castor oil medium. This method is employed to obtain the quantitative results of damping coefficient and quality factor for damped oscillations in different damping medium. The significant results of decrease in damping coefficient and increase in quality factor values with increase in mass, which confirms that more energy dissipation in castor oil medium. The obtained results substantiate that the nature of oscillation of spring mass system is under damped and heavily damped motion in water and castor oil medium respectively.

INTRODUCTION

Oscillation is one of the main topics in Physics course. The simple pendulum is generally recognized to be one of the simplest physical systems in the elementary and advanced Physics course (Mendoza-Arenas et al., 2009; Zonetti et al., 1999). A precise understanding of harmonic motion plays a vital role in Physics from the point of theoretical aspects and experimental observation (Bergomi et al., 1997). The mechanical behavior of this system is well defined and explained using mathematical equations in the undergraduate level. Thorough study shows that the geometry of the spring influences the static and dynamic behavior in the oscillatory system (Triana & Fajardo, 2011). A dynamic system presents a minimum complexity for the study of mechanical oscillations. This is not only important in Physics but also necessary for engineering applications (Firestone, 1933; Triana & Fajardo, 2013).

Research studies have shown that the majority students have learning difficulties in relating concepts with graphical representations(Ambrose, 2007)(Dewi et al., 2018). They require understanding of Physics of harmonic motion in connecting with the mathematical differential equations. Many students learn to solve second order differential equations of motion in their undergraduate curriculum, however, only a few can make out the solutions with the naturally emerging real Physics situations (Shamim et al., 2010). The visual representation of Physics concepts build through computer simulation makes learning effortless (Carlos Castro-Palacio et al., 2013; Sun et al., 2015). The interactive graphical representations provides a supplementary means to understand harmonic motion in terms of displacement, velocity, acceleration etc., (Parnafes, 2010). Nowadays, video analysis in Physics education is acquiring more attention because of its visual display that can make the traditional lecture more interesting along with the effective teaching- learning process (Poonyawatpornkul & Wattanakasiwich, 2013). It stands out as one of the new innovative approaches, which make Physics concepts more appealing and intuitive for learners. Tracker video analysis tool allows users to check rather than simply assume the different physical parameters of the motion. It enables the precise measurement of an object position during motion (Bryan, 2010).

Studies have been done on damped harmonic motion and a diverse repository of experiments performed on different facets of harmonic motion using the traditional methods (Bergomi et al., 1997; Firestone, 1933; Mendoza-Arenas et al., 2009; Zonetti et al., 1999). Recently, a few researchers have investigated and discussed epistemological complexity by using computer-based representations. These include the use of oscillating simple pendulum, swinging on swings, plucking strings of musical instruments, and playing with springs (Parnafes, 2010). The theoretical predictions are easily demonstrated with simple instruments and lend a hand to an introductory Physics laboratory. We are paying attention in damped harmonic motion since it brings an important elementary concepts which are used throughout the Physics curriculum in undergraduate courses. In addition, harmonic motion provides a base for the description of more complicated periodic motion (Firestone, 1933).

Video analysis and image recognition technique are proven methods to analyze oscillatory motion. Further, this opens a new way to understand the complex of physical processes. Research studies using video analysis tools for Physics experiments have been increased significantly as technology has become affordable; this gives ample opportunities for teachers and students to study the Physics of real motion (Poonyawatpornkul & Wattanakasiwich, 2013). For an illustration, a uniform motion, projectile motion, Brownian motion and the Lissajous pattern of spring -pendulum motion, etc. and their experimental observation with mathematical analysis enhances the basics of Physics by acquiring a potential knowledge in an effective way. This technique enhances the pedagogical efficiency contrast to traditional teaching methods necessitate more refined explanation to obtain similar results (Bryan, 2010). Generally, in conventional technique, measurement of various physical parameters of harmonic motion like time period, amplitude, displacement, frequency, phase angle etc., leads to a measurement error. To overcome this, we have used the high speed video analysis tracker tool. It is basically a computer based open source tool, user friendly and supports effective teaching/learning process in an interactive approach (Monsoriu et al., 2005; Ramli et al., 2016; Vavougios & Karakasidis, 2008).

EXPERIMENTAL METHODOLOGY

In the present study, the experiment is carried out in the laboratory where an air resistance is minimal. In the experiment, the light spring of length L = 5.4 cm, diameter of the spring d = 1.27 cm and the number of turns n = 66 is used to study the damped harmonic oscillation. Top end of the spring is connected to the rigid support with the help of retort stand and the lower end of the spring is attached to the mass. The spring constant K = 33.5 N/m is determined by measuring the time period in an air medium. The experimental study conducted in viscous (such as water and castor oil) mediums to study the behavior of damped oscillation of spring mass system(Poonyawatpornkul & Wattanakasiwich, 2013). The experiment is repeated with varying masses viz., 0.200kg, 0.250kg, 0.300kg and 0.350kg at 28^oC temperature. Figure 1 shows the mass attached to the spring immersed in the beaker containing castor oil is placed on a heating bath. The experiment conducted in castor oil medium at temperature ranging from 50^oC to 70^oC.

The harmonic motion behavior studied for different temperatures helps to compare the damping coefficient as a relative measurement of the viscosity of castor oil.

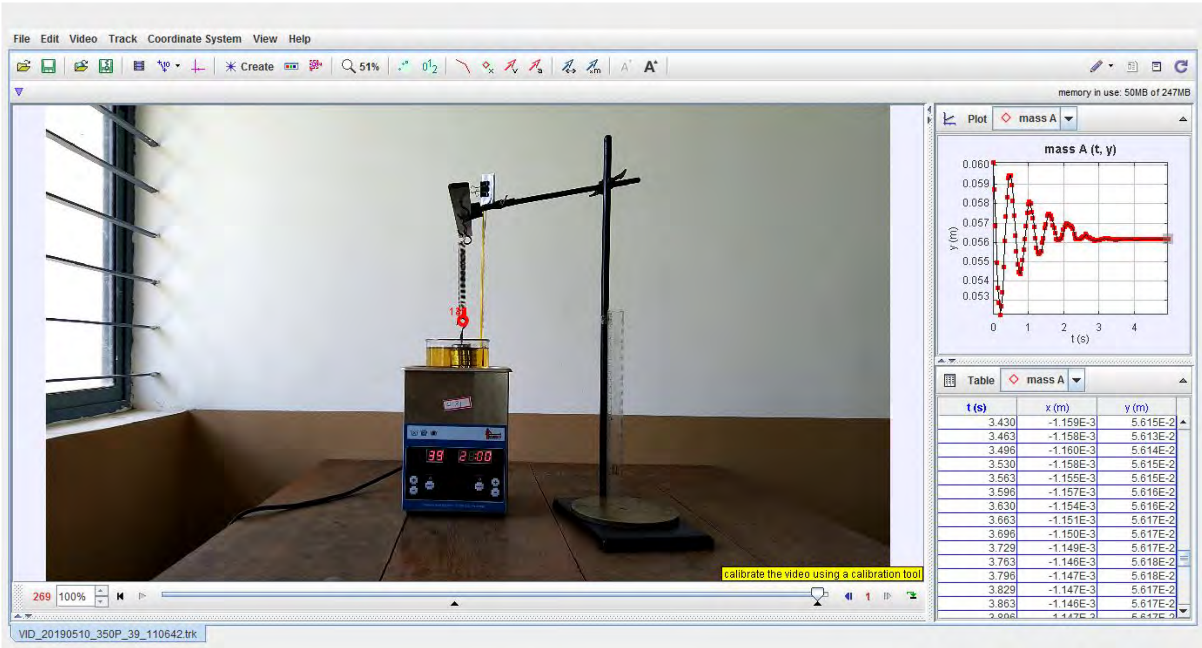

Figure 1: Experimental set up of simple spring-mass system

Video analysis tool is one of the open learning environment combines oscillator motion and graphical representation of position as a function of time (Monsoriu et al., 2005). In the experiment, the frames of oscillatory motion of spring- mass system are recorded using mobile phone camera. It is mounted on the tripod placed at a distance of 1.15m from the experimental setup perpendicular to the plane of oscillation. A measuring scale is fixed to the retort stand which provides a reference length for video calibration. The videos of the experiment are recorded in MP4 format and these are imported and analyzed at the rate of 30 frames per second using the tracker software.

For the video analysis, we need to set coordinate system to calibrate the moving mass. The middle pixel of the mass hanged to the spring is identified as a point mass by the marker to auto track the oscillatory motion. Now, we require second order differential mathematical equation for damped motion and solution to extract the physical parameters from the experimental graph traced by tracker. The solution of the second order differential equation of damped harmonic motion is created in XML format and imported into tracker software tool for the analysis. The coordinates are recorded as a function of time and fit builder data tool is used to analyze the graph to get the required physical parameters. Data Tool application in tracker is used to execute curve fittings. Physical parameters such as amplitude, angular damped frequency, phase angle and damping coefficient are extracted from displacement – time curve to obtain the solution of the harmonic motion.

RESULTS AND DISCUSSION

The main objectives of the present investigation employing the video analysis technique in teaching-learning process of damped harmonic motion are i) to understand the nature of harmonic motion of mass-spring system in medium like water and castor oil. ii) Determination of damping co-efficient in respective medium for the varying mass at a given temperature. iii) Validation of the dissipated energy in respective medium in terms of quality factor for the varying mass at a given temperature.

The present study of spring mass system is considered for viscous mediums. The solutions of the differential equation of damped harmonic motion reveal that the three kinds of damped harmonic motion such as heavily damped, critically damped and under damped motion which mainly depends on the relative magnitudes of damping coefficient (b) and natural angular frequency (ω). We analyzed high-speed videos of a mass–spring system oscillating in water and castor oil at temperature 28°C of different mass from 0.200 kg to 0.350 kg. And also experiment conducted in castor oil for different temperatures. Given this typical treatment of damped oscillators, it was desired to study how well the presence of damping affects the motion of a spring mass system.

Findings in Water Medium

The spring mass system is dipped in viscous (i.e., water) medium completely, to study the behavior of damped oscillatory motion. The oscillating mass is submerged in water, so that buoyancy of water can be treated as stable which causes uniform displacement (y) of mass in water medium. The right hand side of differential equation for damped oscillatory motion is equated to zero by considering constant buoyancy of water.

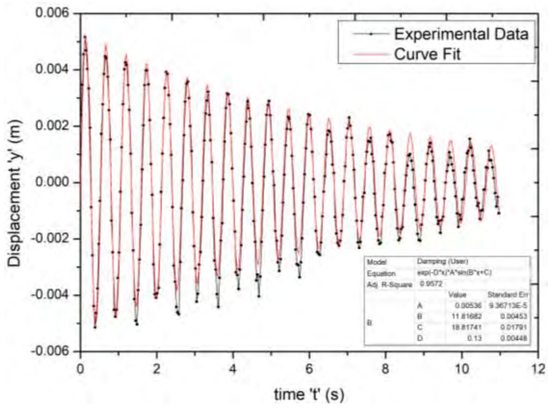

Figure 2: Under damped oscillatory motion in water medium

Mass (kg)	Amplitude (m)	Time Period (s)	Damping Coefficient (b) s^{-1} (Water Medium)	Damping Coefficient (b) s^{-1} (Air Medium)	τ(s)	Damped angular frequency (ω_d)$rads^{-1}$	Quality Factor (Q)
0.200	5.935×10^{-3}	0.511	0.1563	8.47×10^{-3}	3.198	12.28	39.28
0.250	5.334×10^{-3}	0.511	0.1768	3.82×10^{-3}	2.828	12.28	34.73
0.300	7.748×10^{-3}	0.617	0.0946	3.22×10^{-3}	5.285	10.18	53.79
0.350	9.736×10^{-3}	0.663	0.1087	2.88×10^{-3}	4.599	9.46	43.49

Table 1: Physical parameters of the under damped oscillation in water medium

It is very interesting to note from the table 1 that the damping coefficient (b) in water medium with increasing mass is relatively higher than the damping coefficient in air medium. The graphical plot for the mass (0.250kg) in figure 2 illustrate that the exponential variation of amplitude with time. It's observed that the damping coefficient (b) is less than the natural frequency (ω) evident that the motion is under damped in water medium. The quality of the fit can be seen based on the regression coefficient R^2 is 0.96, which indicates the good quality of experimental data that validates the results obtained with the software tool.

It is observed from the figure 2 that the initial part of graphical plot for mass 0.250 kg shows a good agreement between the experimental curve and theoretical curve. A slight deviation in the phase is observed in the graphical plot for all the four masses signifying that the quadratic resistance is no longer dominating the damping term with increase in time for lower velocities.

The energy decay of a harmonic oscillator for four different mass in terms of quality factor is shown in the table 1. It can be observed that the amplitude of the oscillations decreases exponentially, this attributes the energy dissipation due to non-conservative frictional forces. The mean value of ω_d angular damped frequency shows 4.5% error between calculated and experimental values. Theoretically, quality factor should increase with increase in mass. It can be seen from the table 1 that the experimental value of quality factor doesn't shows proper variation with increasing mass. This improper variation may be due to the non-uniform energy dissipation per cycle due to some other frictional terms which is acting on the system not considered in the experiment. The benefit of use of tracker tool helps in the scientific investigation process by providing the visualization of the motion of spring mass system strengthens student's conceptual understanding and train student's skills. By using experimental displacement-time graph learner can identify water medium exerts more damping on spring mass system than air and also the successive diminishing amplitude of vibration lasts in small time in water than air.

Findings in Castor Oil Medium

The experiment conducted in highly viscous (i.e., castor oil) medium. We have analyzed high-speed videos of a mass–spring system oscillating in castor oil of density 959 kg/m^3 at temperature 28ºC. From the curve fitting of displacement –time graph, the physical parameters of harmonic motion are extracted as shown in table 2.

Mass (kg)	**Amplitude (m)**	**Time Period(s)**	**Damping Coefficient (b) s^{-1}**	**τ(s)**	**Damped angular frequency (ω_d) $rads^{-1}$**	**Quality Factor(Q)**
0.200	2.411×10^{-2}	0.567	2.474	0.202	11.07	2.237
0.250	1.162×10^{-2}	0.611	2.587	0.193	10.28	1.987
0.300	2.138×10^{1}	0.690	2.458	0.203	9.095	1.846
0.350	1.587×10^{-2}	0.633	2.243	0.223	9.927	2.213

Table 2: Physical parameters of the heavily damped motion in castor oil medium

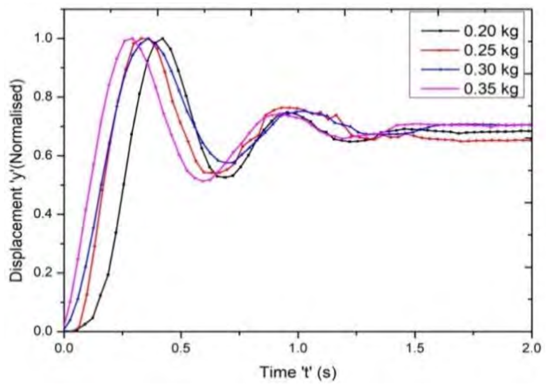

Figure 3: Heavily damped motion in castor oil medium at temp 28°C

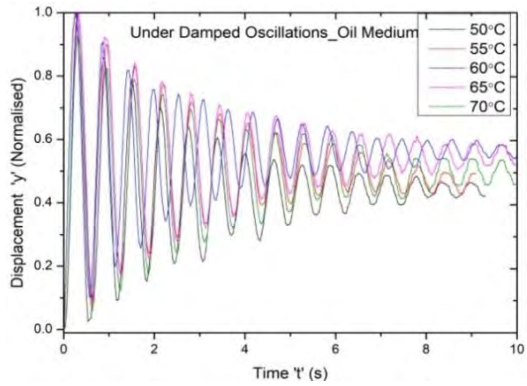

Figure 4: Under damped motion in castor oil medium for the varying temperature

It can be observed from the table 2 that the computed value of damping coefficient 'b' for castor oil medium is of large magnitude when compared with air and water medium. Figure 3 shows graphical plot of spring mass system dipped in castor oil medium with varying mass. It can be observed from the graph that the oscillating mass approaches equilibrium position by oscillating one cycle within 2s. This due to the viscous drag of the castor oil against the moving mass which bring the mass to equilibrium position. This clearly indicates the nature of oscillation close to heavily damped oscillation. Based on the nature of displacement time graph learner can identify increased densities of the castor oil resulting in increase in the damping.

The experiment is conducted to understand the behavior of damped oscillations in castor oil medium with varying temperature (50^0 C and 70^0 C) for the optimized mass (0.350 kg) is presented in Figure 4. It is observed that with increase in temperature, the oscillating mass executes under damped oscillatory motion for 10s duration and then gradually come to equilibrium.

Temperature (°C)	**Amplitude (m)**	**Time Period (s)**	**Damping Coefficient (b) s^{-1}**	**τ(s)**	**Damped angular frequency ω_d rads^{-1}**	**Quality Factor (Q)**
50	1.088×10^{-2}	0.625	0.3477	1.438	10.05	14.45
55	5.804×10^{-3}	0.625	0.3216	1.555	10.04	15.60
60	5.255×10^{-3}	0.622	0.3045	1.642	10.09	16.57
65	7.448×10^{-3}	0.623	0.2879	1.736	10.08	17.51

70	9.365 x 10^{-3}	0.621	0.2814	1.777	10.11	17.96

Table 3: Physical parameters of the under damped motion for the varying temperature

It can be observed from the table 3 that the damping coefficient 'b' decreases with increasing temperature. The relative magnitude of damping coefficient (0.31) is less than the natural angular frequency (9.78). The quality factor increases with increasing temperature due to the viscosity of castor oil that decreases with the increasing temperature. This corroborate the condition correspond to under damped oscillatory motion. The decreasing density reduces the viscous force that oscillates the mass for more number of cycles before coming to the equilibrium position. It is evident from the table 3 that the optimized mass 0.350 kg oscillating in castor oil at a higher temperature 70^{o} C decays at a slower rate than that is oscillating at 28^{o} C because of a larger quality factor. It can be seen from the table 3 that the damped angular frequency remains constant and decay time increases with increase in temperature that causes increasing in quality factor. This helps learner to understand the dependency of liquid viscosity on energy dissipation.

CONCLUSION

The present work used high-speed video analysis technique to study the behavior of a spring-mass system for viscous medium such as water and castor oil. The graphical representation of harmonic function assists to understand the characteristics of oscillations. Video analysis tool enables a richer pedagogical experience and helps to visualize the real path of the damped oscillatory motion which benefits to understand and facilitate to gain the complete knowledge of oscillatory motion. This tool helps to translate the correlation between graphical representation and differential equation. The present work used displacement - time graph to illustrate the path of oscillating mass. The physical parameters such as amplitude (A), damping coefficient (b) and damped angular frequency (ω_d) are extracted by curve fitting. Which substantiates that the nature of oscillation of spring mass system is under damped in water medium. The energy dissipation in different medium measured in terms of Q values. In water and castor oil medium shows inconsistent Q values for increasing mass. The improper variation in damping coefficient and quality factor values shows the non-uniform energy dissipation per cycle may be due to frictional factors which are acting on the system are not considered in the experiment. The significant increase of Q values (table 3) with increase in temperature of castor oil results in decrease in energy dissipation clearly suggests that the under damped oscillatory motion of spring-mass system. The overall investigation gives an idea about the experiment which can be carried out with simple apparatus available in most of the undergraduate Physics laboratories can improve understanding of the concept of harmonic motion which is part of pedagogical and content knowledge.

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TEACHERS' BELIEFS AND PRACTICES RELATED TO USING STORIES AS SCIENCE PEDAGOGY

Punam Medh[1, a, !] and Shamin Padalkar[1, b, #]

[1]Tata Institute of Social Sciences

[a]she/her/hers, [b] she/her/hers

[!]mp2019edp001@tiss.edu, [#]shamin.padalkar@tiss.edu

Several studies in science education have proposed that stories can be effective in teaching science and nature of science (AAAS, 1989; Conant, 1951, 1957; Klopfer, 1969; Abd-El-Khalick, 1999; Clough, 1997, 2004, 2006, 2011; Allchin, 2013;). In non-academic spaces too, stories for teaching science are extremely popular. But does academic validation and mass popularity reflect in the science classroom? We conducted a study with 20 science teachers from government and low cost private schools to find out whether they used stories while teaching science. Using semi-structured interviews we first tried to understand teachers' conceptualization of the aims of teaching science and their favoured pedagogies for achieving these aims. Next, we asked them whether they used stories and how often. For most teachers, scientific literacy was an important aim for teaching science which could be achieved through pedagogies like reading from the textbook, using examples, analogies and demonstrations. We found that even though none of the teachers named stories as pedagogy to teach science, when asked, a large percentage of teachers confirmed using different types of stories, albeit spontaneously. This proclivity of teachers for narrating stories needs to be leveraged by sensitizing them about the potential of stories to teach content and nature of science and also by providing them with suitable stories that can be readily used in the classroom.

INTRODUCTION

In the 1st century BCE, a Roman architect named Vetruvius wrote the De Architectura. In the introduction to the ninth volume of this collection of books, Vetruvius added a small fictitious story about Archimedes discovering the laws of buoyancy while sitting in a bathtub (Biello, 2008). Today, almost everyone who has learned the laws of buoyancy in school is likely to have heard the Archimedes story. The inclusion of stories while teaching science, whether to generate interest or to teach a scientific concept more effectively, is an age-old practice.

The idea of using stories and narrative forms to communicate science persists in science education and one of the earliest examples in more recent times can be traced to The Harvard Case Histories in Science (1957) edited by James B. Conant, President of Harvard University from 1933 to 1953. These narratives of experiments helped convey what Dr. Conant described as the 'feel' for the 'tactics' and 'strategy of science' (Ed. Conant et al. 1957). The effectiveness of using stories in science has since then been supported through research, policy documents, through science textbooks and also in popular science.

Bruner (1985), proposed that the narrative mode, by virtue of its exaggeration, paradox and contradiction, can help draw out meaning for students (Bruner, 1985 cited in Martin & Brouwer 1991). There are several studies that show that stories and narratives of scientific discoveries are an effective way to introduce students to nature of science and the values and beliefs inherent to scientific knowledge (Lederman, 1992; Abd-El-Khalick & Lederman, 2000;

Vanderlinden 2007). Science, by the virtue of its discoveries and inventions, can be readily cast into narrative forms. These narratives, when situated in the socio-cultural and political contexts within which they took place, address deeper aspects of science (Klassen, 2009).

More recent scholarship on stories in science include a six-week research study investigating socioeconomically disadvantaged students' responses to oral stories in a school in South Carolina. It was found that students eagerly awaited stories each week and used them as clues to understand science (Renard et al, 2016). Similarly, Morais et al. used a storytelling approach to teach concepts of acids and bases in chemistry to children aged 12-14 years who in turn experienced creating stories for preschool children. The study found that the experience of hearing, creating and retelling stories to younger children for learning science proved beneficial to both groups for learning science (Morais et al., 2019). In another study, biology teachers used a storytelling approach to teach the cell division sequence to grade 10 children. The results showed that the use of storytelling could enhance students' scientific literacy, scientific discourse and problem-solving competence (Martin et al, 2021).

In India, policy documents like the NCF 2005 and NCFTE 2009 encourage the use of stories in the classroom. The NCF position paper on Science states "Narratives giving insights on the historical development of key concepts of science should be integrated into the content judiciously" (NCERT 2005). Most school level science textbooks often include short stories of scientific discoveries. However there is no specific pattern or logic as to which topics may be accompanied by a story. Moreover, these stories usually appear in blurbs and are not a part of the main text.

Science popularization leverages the potential of stories and narrative to the fullest. The German program 'Die Sendung mit der Maus', often called 'School of the Nation', telecast in 1971, is still popular among children world-wide. This program with characters like a mouse and a blue elephant, uses narrative elements to teach young children how to make electricity from lemon juice or how hot air balloons fly. In the early nineties, Indian television ran a weekly science magazine called 'Turning Point' that used narrative form and elements of drama to convey scientific facts in an engaging manner. Today, video-based online platforms host channels like Physics Girl and ASAPScience that convey scientific concepts using stories and narratives are immensely popular and enjoy viewership in millions.

RESEARCH QUESTIONS AND METHODOLOGY

Stories, it can thus be said, are a pedagogy supported by research, are given due importance in policy and are also freely available in non-educational spaces. Does this acceptance and popularity of stories in science communication reflect in the practice of teaching. This study aims to understand teachers' belief and practice about the use of stories while teaching science. Based on the aforementioned review of literature, we formulated the following research questions for this study:

1. What kind of alignment is seen between teachers' conceptualization of the aims of teaching science and the pedagogy they use?
2. How often do teachers tell stories while teaching science?
3. Are these stories planned or spontaneous?
4. What kind of stories do teachers use while teaching science?

We identified five schools following the Maharashtra state board science syllabus. Two of these schools were government, English medium schools, one was a low-cost private English medium school, one was a government, Urdu medium school and the fifth was an English medium private school. A non-English medium school was chosen to explore whether local cultures and folk tales were reflected in the data. We selected 20 teachers, teaching science at the secondary level (Grades 8-10) except one who taught at the higher secondary level (Grade 11-12). Of these, 11 teachers were graduates with a B.Ed. degree, four teachers were post graduates, two teachers were post-graduates with a B.Ed. degree and one teacher had a B.E. degree and one teacher had a diploma.

This was a qualitative study. The tools designed for data collection were 1) Semi-structured interview and 2) A post-interview follow-up

DATA COLLECTION

The interview schedule was structured around 4 themes: a) Teachers' conceptualization of the aims for teaching science b) Pedagogical methods for teaching science c) Whether or not teachers use stories and d) Practices around the use of stories such as lesson planning. The first two themes were conceived to understand the context within which teachers would respond to the questions on the use of stories. To collect data on the use of stories, we told teachers that if any of the following are used, they could be considered as stories; current scientific events, personal events or narratives related to science, myths and folktales related to science, stories of discoveries and inventions and stories from the science textbook.

After the interview, we carried out a follow-up with 11 out of the 20 teachers who volunteered to report their daily use of stories for 10 teaching days via instant messaging or phone calls.

FINDINGS

The interview data was tabulated based on the four broad themes of the semi-structured interview questions and coded. Two authors independently coded 20% of the data and the inter-rater reliability was 95%. Presented below are highlights of the coded data from the semi-structured interview.

Correspondence between teachers' conceptualization of the aims of teaching science and their choice of pedagogy

Almost 50% of the teachers conceptualized the teaching of science as being connected to understanding how things work in daily life. Some of the examples of daily life they quoted were 'changing a fuse in the house', 'movement of sun and earth' and 'what to do when someone in the house falls ill'. Table 1 shows a list of the aims teachers have for teaching science, and as can be seen, developing scientific literacy is the most commonly stated aim of teaching science.

Aims of Teaching Science (n=20)	**Frequency**
Developing scientific literacy (how things around us work, removing superstition)	15
Developing cognitive skills (like data analysis, critical thinking etc)	7
Preparing for professional courses in STEM	3
Solving global/societal problems/progress of human race	3

Search for truth or philosophical reasons	3

Table 1: Teachers' conceptualization of the aims for teaching science

Given these aims, what were the pedagogies used by teachers? Teachers' favoured pedagogies for teaching science are listed in Table 2.

Pedagogy Used by Science Teachers (n=20)	Frequency
Lectures/reading from textbook	18
Examples and analogies from daily life	17
Demonstrations and observations	11
ICT	10
Classroom discussions	7
Diagrams, charts and other visual representations	7
Experiments and tinkering	2
Problem-solving	1
Story	1

Table 2: Teachers' listing of pedagogies for teaching science

As seen in Table 2, 90% teachers reported the lecture method which confirms our intuitive notion about classroom discourse. That it figures so prominently in this list is a potential area of concern. However, a point to be noted here is that, even though textbook reading and lecture occupied the top slot, it was certainly not the first pedagogy listed by the teacher, in fact, it was among the last.

'Using examples and analogies' emerged as the second most prominent pedagogy, followed by 'demonstrations'. Both of these were among the first, readily reported pedagogies. To support this, they gave examples of demonstrations they had recently done in class; such as separating salt and sugar for explaining states of matter or demonstrating density of liquids like water, vinegar, milk, oil and kerosene.

Use of ICT closely followed demonstrations and observations. A few teachers stated that they utilized videos curated from popular online video platforms. In one of the government schools, science teachers had recently received training on conducting smart searches for curating science videos and animations. In this school, all teachers reported ICT as a pedagogy, in fact a favoured pedagogy. It is interesting to note how ICT itself was seen as a pedagogy here – though it can include many different media such as videos and simulations, and approaches such as e-learning tutorials and lectures. Research posits that very often the use of ICT is unclear; it is sometimes used as a 'servant' to reinforce existing teaching methods, or it is used as a partner to change the way teachers and pupils interact with each other and with tasks (Cox, et al., 2004). In this case it seemed more of the former, where students passively watched ICT resources like videos and animations related to textbook topics from the textbook.

An interesting finding here was that only one teacher reported using story as a teaching method.

This could be because she had recently attended a 'Stories in STEAM' workshop.

We used cross tabulation and colour codes to see whether there was a correspondence between aims of teaching science and pedagogical choices. We found that teachers for whom science is a way of understanding daily life are more likely to use pedagogies like demonstrations, examples and analogies. As such, we found that there tends to be a correspondence between teachers' conceptualization of the aims for teaching science and their choice of pedagogical methods.

Extent of story usage in class

Although only one teacher spontaneously reported 'story' as a method of teaching science, 85% teachers confirmed that they used stories when they were explicitly asked about it. Most teachers from this pool of 85% enthusiastically shared why they think stories are important and also shared several examples of how they used it. One teacher, for instance, shared that while teaching a chapter on friction, she shared a personal narrative of playing '*chatka*' (sting) with a red seed commonly found in that area. The play was to rub the seed on the ground and when it generated enough heat, it was fun to touch this hot seed to an unsuspecting friend's skin to startle the friend. What is noteworthy about this narrative is that the teacher has taken the example of the seed and wrapped it in her personal memory and cast it as a personal narrative to perhaps create a greater degree of engagement (Martin & Brouwer, 1991). Similarly, another teacher, while teaching a chapter on health and nutrition, used a blood report wrapped around in a personal narrative to make the discussion engaging and interactive. Teachers shared their examples of the current events that they discussed, like the *Chandrayaan* II mission and the Australian bush fires that were in the news at that time. A few teachers, even though they did confirm using stories, felt that stories were suitable only for the primary section students. Three (15%) teachers said that they did not use stories because they felt it was not suited for teaching science or they did not know that a story could be used in teaching science.

After the semi-structured interview, a follow-up for 10 teaching days was conducted with 11 of the 20 teachers. Number of stories told during the 10 day follow-up period along with the number of teachers who reported that they told that many stories are given in Table 3.

Number of stories told	11	9	8	6	5	5	4	3	2	0
Number of teachers (n=11)	1	2	1	1	1	1	1	1	2	1

Table 3: Number of stories told by teacher during 10 days of follow-up period

Table 3 shows that on average each teacher told one story every other day and that 50% of teachers narrated five or more stories in 10 days. This finding leads to thinking about whether these stories were a result of planning or did they come about spontaneously?

Were the stories planned or spontaneous?

From the pool of 85% teachers who confirmed they used stories, only one teacher reported the planning of using a story. This planning was also evident in the kinds of stories she narrated which included current events, personal narratives, myths and folklore (about the *Bishnoi* rulers) and several narratives on socio-scientific issues. Nearly 60% of teachers however reported that their use of stories was both planned and spontaneous. For example, several teachers said ‘sometimes we plan, sometimes it immediately clicks’. And 35% of teachers said that the use of stories was only spontaneous. Using this data, we infer that teachers used stories, spontaneously, as and when the opportunity presented itself during the discourse. This is further supported when we look at the kinds of stories that teachers used.

Stories used in class

Based on the reports of the stories that were narrated by teachers in 10 teaching days, it was found that they broadly fit in the following categories; a) stories of discoveries and inventions (from outside and within the textbook) b) description of current events c) personal narratives about science and d) stories like myths and folktales. Table 4 gives the number of each of the above types of stories based on what teachers reported in the follow-up.

Type of Stories	No	Some Examples
Stories of discovery and inventions (from the textbooks and outside of it)	23	The story of Greek scientists Thale and Archimedes, a detailed account of the discovery of electricity sourced from outside the textbook, discovery of X-Rays by Roentgen.
Current events	18	*Chandrayaan* mission II, Australian bush fires, increasing incidents of flooding in many Indian States.
Personal narratives about science	13	On gender identification of a foetus (from socio-scientific perspective), personal narrative about choosing a career in science, myths around handling pickles during menstruation.
Myths and folktales	5	Folktales about the *Bishnoi* community who cared for trees and environments, a story (or a myth) about a man who acquitted himself using knowledge of chemistry, forest man of India - Jadav Payeng.

Table 4: Stories told by teachers (n=11) during the follow-up period of 10 days and frequency of each kind of story.

CONCLUSION AND DISCUSSION

Stories are a powerful way to contextualize scientific knowledge in the larger socio-cultural landscape, without which it runs the risk of becoming a dry compendium of facts and formulae. In our study we found that most (85%) teachers confirmed that they often use stories while teaching science, though a few (10%) believed that stories were more suited for younger children. More than 50% of teachers from this pool evidently told at least one story every other day. Teachers told stories that appeared in the textbooks, current events, personal narratives and occasionally popular folk tales. For most teachers the purpose of telling stories was to generate interest and connect the forthcoming topic to daily experiences. This too is consistent with the finding that almost all stories were told spontaneously. It follows that even though teachers have a proclivity for narrating stories, they do not consider stories as a formal pedagogy suited for teaching the content and nature of science.

It has probably always been apparent to good teachers that stories make learning experiences memorable. However, there are no theoretical frameworks for creating science stories, nor are there established theoretical approaches on how stories can be used (Klassen, 2009). Thus on one hand, stories and the narrative form have a great potential in science education and on the other hand, teachers do like to tell stories while teaching. However, teachers are unaware of the potential of story as an effective and unique pedagogy to teach certain aspects of science. This gap needs to be addressed by educating teachers on using stories and providing them with well-designed stories. Just as experiments and activities are designed to address specific pedagogical purposes, an abundance of stories which are designed around school science need to be available for teachers to tell in the classroom. Moreover, these stories could be presented using different media, available through various channels, to ensure a maximum outreach. We are hoping to take this forward by designing age appropriate science stories tied to specific learning objectives.

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THE NATURE OF MULTI-, INTER-, TRANS-DISCIPLINARY STEAM EDUCATION CURRICULUM IN NEPAL

Netra Kumar Manandhar, Bal Chandra Luitel, Binod Prasad Pant, Indra Mani Shrestha, and Niroj Dahal

Kathmandu University School of Education, Hattiban, Lalitpur, Nepal

he/him/his, he/him/his, he/him/his, he/him/his, he/him/his

netra@kusoed.edu.np, bcluitel@kusoed.edu.np, binod@kusoed.edu.np, indramani@kusoed.edu.np, niroj@kusoed.edu.np

The long tradition of the conventional nature of education characterized by a behavioristic model of educational practices in Nepal and beyond appeared as unhelpful and disempowering enterprises. Such a model of education survived under the compartmentalized nature of curriculum where pupils did not find the connection of one discipline/subject to others as well as the connection of curriculum materials to the real lifeworld. More so, the existing discipline-based education focused on rote memorization of the facts and information without focusing on 21st-century skills. In such a context, there was a visible change in education from Kathmandu University to start a popular program – STEAM Education. With the increasing awareness of people in the program, schools are now implementing STEAM as a pedagogical approach. Similarly, there is a good initiative from the government of Nepal to implement an integrated curriculum from 1 to 3. In such a context, there should be an authentic model of a curriculum which serves the principles of STEAM education. This paper was extracted from the first author's MPhil dissertation. Employing argumentation as a method of inquiry, this paper explores the various curriculum dimensions of STEAM education in the context of Nepal. The data came from the experiences of the author's experiences as a STEAM advocate, a teacher educator, and a STEAM-based program developer. The findings of this paper can be significant for everyone who is seeking change through STEAM education.

Keywords: STEAM Education, STEAM curriculum, Holistic Education

THE DISCIPLINARY BOUNDARIES IN EDUCATION

The nature of curriculum as a subject matter to be taught and curriculum as discrete tasks and concepts have become the dominant factors for the reproduction of knowledge. These curriculum images as discussed by Schubert (1986) are the foundations for the existing context of education which promotes the memorization of facts and information, value of collection of algorithms and rules, decontextualized contents and concepts, and eventually the compartmentalization of disciplines and subjects (Pant et al., 2020; Manandhar, 2021). In such a situation, content knowledge is provided as information by assuming students grab it having a complete mastery on it and by ignoring the essential life skills. The focus of discrete tasks and concepts to prepare a student as an expert in a particular field has become a taken-for-granted assumption. As a result, there appear to be boundaries among the subjects as if they were developed in the different planets. The pedagogical practices drawn from such images of curriculum prioritize the technical and sometimes practical human interest, thereby ignoring students' inherent capabilities, diversities, and skills for solving the complex real-world problems.

In the disciplinary boundaries, disciplines are taken to be separate and distinct from one another. For example, mathematics and science are different, and there needs to be different and separate abilities to deal with the concepts in these subjects. Consequently, teaching and learning practices follow the disciplinary-centric nature of education with a separate teacher, separate routine, separate table of contents, separate pedagogy, separate assessment practices wherein a particular student or teacher is not able to link academic contents to other disciplines; moreover, s/he does not find the application of disciplines/subjects in day-to-day life. In existing and conventional model of education in Nepal and other countries, subjects are divided separately, curricula are developed for separate subjects, teacher preparation programs are designed based on the disciplines/subjects, and execution of knowledge delivery runs for separate subjects (Pant et al., 2020; Aguilera & Ortiz-Revilla, 2021). This might be one of the reasons for having a poor performance of the school students in higher cognitive abilities such as applying, analyzing, evaluating, and creating (Education Review Office [ERO],2020). ERO also claims that students are weak in conceptual understanding, critical thinking, creativity, etc. Moreover, this could be the reason behind having unsatisfactory achievements of the students at all levels (Poudel, 2017) and educational experiences being largely negative (Pant et al., 2020).

STEAM EDUCATION IN NEPAL

The situation of fragmenting subjects and disciplines needs a complete reform in education to break the boundaries of subjects/disciplines in the contexts of Nepal. Nepali educators (e.g., Pant et al., 2020; Shrestha, 2018, Pant, 2015) have emphasized on integrated nature of curriculum, innovative and progressive pedagogical practices, authentic and performance-based assessment strategies in education to make holistic education work. The initiation of STEAM Education program at Kathmandu University is one of the changes we can consider. This educational model is emerging and gaining popularity all around the world (Pant et al., 2020; Perignat & Katz-Buonincontro, 2019). Here, STEAM is an acronym for five interconnected subjects: science, technology, engineering, arts, and mathematics. These most common and essential four subjects are inextricably connected, and the STEAM approach is supposed to present contents through the usage of arts, and this seeks an integrative nature of the curriculum. National Curriculum Framework for School Education (NCF) (2019) of Nepal developed a policy for developing an integrated curriculum, and it has been implemented from 2020 throughout the nation. The major emphasis of this curriculum is to use the thematic method of teaching and learning with the help of multidisciplinary and interdisciplinary curriculum integration, which allows integrated learning (NCF, 2020). In this, the curriculum organizes interrelated disciplines and learning contents to promote integrated learning experiences and develop interdisciplinary skills focusing on transversal skills (UNESCO, 2015). So, this is one of the initiations by the government towards integrated learning.

The central principle of STEAM education is to emphasize integrated learning through multi-, inter-, and trans-disciplinary curriculum integration which helps students to connect academic subjects/disciplines with their real-world and do continuous innovation in various areas. It includes the innovative pedagogies such as inquiry-based, project-based, technology-enhanced, arts-based (storytelling, dancing, sculpturing, etc.) pedagogies that help students develop their communication, collaboration, creativity, critical thinking, curiosity, etc. In the importance of arts, Eisner (2002) emphasizes the role of arts by saying, 'education, in turn, is the process of learning to create ourselves, and it is what the arts, both as a process and as the fruits of that process, promote' (p. 3). To transform the human consciousness, arts could play a crucial role which is not only the way of creating performances and products; it is the way of creating our lives by expanding our consciousness, shaping our dispositions, satisfying our quest for meaning, establishing contact with others, and sharing a culture (Eisner, 2002). In the same line, Sousa and Pilecki (2018) illustrate the benefits of arts integration in learning, such as arts engage the young brain, develop cognitive growth, advance social growth, introduce novelty, improve long-term memory, reduce stress, and make teaching more interesting. Moreover, arts help to develop empathy can be a powerful tool for releasing the imagination for possible social transformation and actions (Greene, 1995) wherein 'aesthetic experience as a means might awaken students' consciousness for advancing democratic values with multiple perspectives, freedom, and responsibility' (Moon et al., 2013, p. 223). Thus, STEAM education is powerful through integration of arts.

RESEARCH PURPOSE

The purpose of this argumentative paper is to explore curriculum dimensions of STEAM education for the effective implementation of STEAM education in the context of Nepal and beyond.

THEORETICAL PERSPECTIVE

We used constructivism learning theory in this paper. Constructivism believes that the knowledge construction process is active learning where learners are at the center of learning activities, and they engage actively to construct knowledge (Major & Mangope, 2012). In this, knowledge is made or constructed by learners, but it is not given. In the process of learning, via the constructivist eye, a continuous adaptation (von Glasersfeld, 1995); active interaction among peers, people, and materials are essential to collaboratively create knowledge, etc. For STEAM education, the pedagogical and assessment practices are more innovative and progressive which are the product of constructivism learning theories.

Moreover, we also used the holistic education concept as a referent in this research. The primary emphasis of holistic education is on the overall development (i.e., physical, emotional, intellectual, social, aesthetic, and spiritual development) of the individual (Mahmoudi et al., 2012; Rudge, 2010). Amid the major concerns of the present model of education in the development of basic knowledge and skills, holistic education advocates for nourishing the inherent possibilities of human development, thereby connecting an individual to life, society, the worlds, and the entire cosmos. By supporting this, one of the holistic educators Ron Miller (2006) admits, "Holistic education aims to reconnect each person to the contexts within which meaning arises: the physical world, the biosphere, the local community, the culture with its many layers of meaning, and the cosmos itself" (p. 29). Here, we advocated for arts-integrated, technology-integrated, and transformative methodologies of teaching (learning by doing and reflecting). Similarly, the major emphasis of the integrated nature of curriculum seeks a balance between mind and body, linear thinking and intuition, self and community, and various domains of knowledge striving for developing a conscious awareness of the relationship between the earth and the soul (Miller, 2000, 2007). From the Eastern holistic education perspective, arts integration in teaching and learning practice is the primary means for self-transformation by pursuing the higher self and spirituality (Nakagawa, 2000, 2018). Since STEAM integrates arts, so STEAM provides the opportunities for spiritual development as well. The constructivism learning theory is essential for my argumentation to discuss the learning from constructivism vantage points such as discovery learning, and holistic education concept is important because I am arguing ideas from the integrated/interconnected framework of education.

RESEARCH METHODOLOGY

The paper was extracted from the first author's MPhil dissertation in STEAM education which was centralized to the perspectives of STEAM education to connect academic and non-academic life-worlds of students. The second author was the supervisor of the research and remaining authors were the critical friends who provided feedback throughout the research process. The dissertation was done by using the evocative autoethnography Method wherein the author presented his lived experiences of being student, teacher, and teacher educator in the educational context of Nepal through critical reflexivity and transformative educational perspectives. This paper was developed through argumentations as a method of inquiry where we tried to justify and validate the ideas through a rigorous review of recent literature. Similarly, the theories were used as referents for making the discussion more evident and authentic. The data were collected from the experiences of the authors, reflections from the schools and teachers who use STEAM education as a curriculum and instruction practice, and available recent literature in STEAM education. Therefore, this paper guides educational stakeholders especially teacher, educators, curriculum developers to shift practices from traditional separate discipline centric educational model to integrated and holistic education system.

FINDINGS AND DISCUSSIONS

The Nature of STEAM Curriculum

Formal education was seen to be separated from the life-worlds of people as if academic subjects might come from segregated planets. Students used to study eight or more subjects such as Mathematics, English, Science, Social Studies, Nepali, including others with separate teachers in the archaic model of education and curriculum that might be unsuccessful in many ways which force students to learn in a narrowly conceived and bounded criterion or objectives of the separate subjects. Moreover, it seems that students are not likely to be capable of real-world application of those ideas and skills learned in the formal academic setting (Pant et al., 2020). For instance, a student's family has a vegetable garden, and his/her parents in the business of selling those vegetables in the local market. However, s/he might not have the ability to help parents in their household chores and business with those formal academic experiences. The situation might present the context of how formal education and life-worlds of students are separated. So, the context is apparent for a big failure of education as there are issues such as disengagement, disinterest, negative attitudes, raising dropout rates, unemployment, among other critical issues. As a result, that seems to be a factor to negatively affect the progress of individual as a person, society, and the world. However, the STEAM curriculum can be useful for solving these issues.

The contemporary integrated curriculum of Nepal has been governed by the notion of interconnectedness: a holistic educational principle that every element in this world is interdependent – one can exist depending upon the other (Nakagawa, 2000; Rudge, 2008). There are three forms of curriculum integration: multi-, inter-, and trans-disciplinary. If we put these in a continuum of curriculum integration, multidisciplinary nature lies within the least integrative form of integration which involves the knowledge, processes, and skills more than one discipline through theme-based teaching. In this regard, the present integrated curriculum of Nepal seems to be heavily guided by the notion of multidisciplinary integration. To understand this, let us take a project which was done in one of the institutional schools of Kathmandu, 'kitchen garden' could be a theme. Now, the concepts and skills of several disciplines or subjects can be developed, centralizing this theme. Teacher can teach several concepts of science (soil, plant, environment, etc.), mathematics (area, height, patterns, numbers, basic operations, etc.), engineering and technology (designing the plot, researching through internet), and arts (making garden appealing to other or could write poems/songs or make a painting of beautiful kitchen garden, the humanity of being together, etc.). The subjects or disciplines are organized in a theme rather than an orientation towards an authentic problem (Wickson et al., 2006). So, this approach of curriculum integration might not be helpful because there is still a space for separate disciplines to be predominant or we can still separate the disciplines. This might be a starting point for STEAM education as a pedagogical approach but how can teachers integrate real-world problems faced by students and a larger community of people? Interdisciplinary and transdisciplinary natures must be the features of STEAM curriculum. Interdisciplinary approach perhaps emphasizes on common interdisciplinary skills and concepts embedded in disciplines wherein knowledge is socially constructed, having many right answers (Drake & Burns, 2004). In this approach, students and teachers involve in collaborative projects to address specific 'real-world' problems and, as a result, encourage students to create new knowledge across the disciplines (Stock & Burton, 2011). For instance, the above example (Kitchen Garden) can be applied in interdisciplinary teaching and learning if we allow students to ask questions across several disciplines with the motto of cultivating interdisciplinary skills and we put some real-world issues like how you would save your kitchen garden from predators. What happens to vegetables when suddenly the weather changes? This might enrich students' 'thinking out of the box' skills with real-world application of knowledge. In doing so, they can develop a kitchen garden through painting, or they can develop a song related to the same to make learn fun and effective. The transdisciplinary nature of STEAM curriculum is a paradigm shift in curriculum integration that might fundamentally focus on a real-world problem-solving approach (e.g., through project-based learning) wherein students are encouraged to develop life- affirming skills as they apply interdisciplinary concepts and skills in a real-life context (Drake & Burns, 2004). This might often go beyond the disciplines while producing a new perspective (Gibbs, 2015). Students, whilst solving authentic problems, could develop creativity, ingenuity, curiosity, imagination, critical thinking, productivity, and accountability. Let's understand this through an example. We are taking one of the major earthquakes of around 7.5 rector scale that happened in 2015. The project can be following:

> *You might have experienced the last earthquake of a 7.8 magnitude on April 25, 2015, in Nepal which epicenter was in place A and caused serious damages and killed several people and other lives. Earthquakes can happen frequently and anytime (minor or major earthquakes). Now, your and your team's job is to determine whether or not another earthquake of a 10.0 (or double 15.6) magnitude could ever happen in the place B. While doing this project, predict the epicenter; discuss the potential impact on people's lives, place's infrastructures, economics, education, etc. Gather the information/evidence by talking to higher authorities or more knowing others (or people in the community) or use technologies to explore the facts and solutions (how to minimize the impacts on life and environment). Also, come up with some models or representations (pictures, paintings, etc.) to portray your creative imagination of the future which is/are useful to minimize the impact of the earthquake. Moreover, create a model of earthquake resistant village or city (including the design of homes).*

Thus, this might be one example in which students can be engaged in project-based or problem-based learning scenarios by interacting the world around them that integrates concepts and skills of multiple disciplines, problem-solving approach through real-world application experiences, and essential 21st-century skills, including metacognitive and creative imagination skills. Here, the emphasis is on the problem-based centralization of curriculum as Beane (1995) discussed that curriculum integration begins with the idea that the sources of curriculum ought to be problems, issues, and concerns posed by life itself wherein concerns generally falls under self or personal and issues and problems posed by the larger world. In this case, interdisciplinary and transdisciplinary approaches seem to be appropriate. In doing so, we are not against of multidisciplinary curriculum integration because it could be the starting point of shift in education.

STEAM curriculum could be locally and contextually designed based on the guidelines provided by Curriculum Development Center (CDC) under the ministry of education. Thus, the guidelines can be crucial framework for developing curriculum synergistically by teachers together with students and members from community. In this regard, the curriculum now might have become the representation of the balanced nature of local and global perspectives (a Glocal view); modern and traditional knowledge systems; depth and breadth; knowledge skills, characters, and meta-learning, outcomes, process, and praxis; and the mind, the body (including heart), and the soul. While doing this, the curriculum appears to be the portrayal of the needs of local people, student-centered, and adaptable based on the emerging evolutions in the world. The adaptable nature of curriculum seems to be flexible, and a living document or framework of learning based on what the world is becoming, what it needs, and the best ways to achieve our individual and collective goals through education (Fadel et al., 2015). With this nature of the curriculum, it appears to be able to include potential breakthroughs in the world such as technology; to address students' needs, interests, and personal growth goals; and to explore outside the school environment for creating diverse learning opportunities for learners for deep and rich learning experiences.

Another focus of STEAM curriculum should be the value of ecological consciousness which might be one of the fundamental elements of holistic education (Nakagawa, 2000). This probably gives rise to the basis for knowledge systems arising from local cultural practices of people. Zhang (2006) considers the notion of ecological consciousness as 'acknowledging the rightful co-existence of humans and the non-human aspects of nature, thereby realizing inseparable relationships between nature's different forms of lives' (as cited in Luitel, 2009, p. 297). This might be necessary to promote Nepali Cultural Worldview offering a basis for viewing, knowing, valuing, being, imaging, imagining, and envisioning the importance of co-existence. For instance, Luitel and Taylor (2005) argued that the primary notion of contextualization of mathematics curriculum is to ensure the inclusion of local knowledge traditions as the curriculum content. As we know our multicultural society is more likely to respect all the existences of the world, considering one existence is interdependent and inseparable from the existence of the other. In this view, the curriculum could be inclusive and empowering for the culturally contextualized education that helps us incorporate local knowledge wisdom traditions arising from everyday cultural practices of people.

REFLECTION AND LESSON LEARNT

The disempowering and conventional nature of the existing curriculum serves the technical interest of human thereby emphasizing on textbook-based problem algorithmic problem solving, memorization and rote recall, lower-order thinking abilities which are some of the reasons of dissatisfaction and decreasing interest of people in education. Considering curriculum as a subject matter to be taught, as a collection of discrete tasks and concepts, and as a reproduction of knowledge is being unhelpful to produce skillful, aware, and creative human being who can be agents of change for society. The disciplinary nature of curriculum and instruction is not allowing students and teachers to think beyond the disciplinary boundary for exploring the connection of academic contents and the real-world. However, in the context of reforming and transforming nature of curriculum as discussed by Schubert (1986), such as curriculum as experience (building knowledge and skills based on students' prior rich knowledge and experiences), as social reconstruction (building awareness to make an equitable and inclusive society through empowerment, freedom, and autonomy), as currere (learning from critical self- reflection) are being helpful for the quality change in society by transforming the values, skills, and knowledge to students. So, STEAM education is grounded in, but not limited to, in these three curriculum images.

As far as holistic and constructive models of education are concerned, education should foster the required knowledge and 21st-century skills among students so that they can solve the complex problems available in their surroundings, day-to-day life, or the world. For this, the integrated knowing and knowledge of more than one field are necessary conditions to research the problem holistically and solve them because the problems faced by people and other beings in the world are complex and interconnected. STEAM education is grounded in the concept of integrated learning promoting science, technology, engineering, and mathematics in education, and they can be learned effectively and in a fun way through arts-based methodologies such as storytelling, sculpturing, poetry, singing, dancing, painting, etc. Moreover, arts can be useful to study not only STEM but also history of science and philosophical ideas and discourses in a meaningful way. Similarly, for the continuous innovations to make life easier in this world and maintain ecological sustainability, students must be exposed to learning experiences having rich hard skills, higher-order thinking skills, transformative sensibilities (critical consciousness, ecological consciousness, metacognition), and affective dimensions related skills. For this, teachers need to be prepared and skilled to use various constructivist and transformative methodologies of teaching (e.g., project and problem-based learning) under the transdisciplinary nature of an integrated curriculum.

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STRAND 4: RESEARCH TO PRACTICE IN DISCIPLINARY AND INTERDISCIPLINARY SPACES

A MODEL FOR THE INTEGRATION OF PEDAGOGICAL CONTENT KNOWLEDGE IN TEACHER TRAINING PROGRAMMES

Serah Suman Potharay[1, a, !] and Umakanth Dammalapati[1, b, #]

[1]Department of Education in Science and Mathematics, Regional Institute of Education (NCERT), Manasagangothri, Mysuru-570006, Karnataka, India

[a]*she/her/hers,* [b]*he/him/his*

[!]serahsuman@gmail.com, [#]umakanthd@riemysore.ac.in

Teacher Education Programmes, undoubtedly, play a crucial role in making future teachers for educating the next generation of students in the building and progress of a nation. These programmes are being continuously reframed to the requirements of a society. However, there exists a wider gap in the implementation, execution and sometimes in the design of the courses to fulfil the present day or future necessities. Proposed in this work is a model called, Coupled Class Model (CCM) emphasizing the integration of pedagogical content knowledge and subject matter knowledge thereby assuring effective simultaneous delivery of the same to the teacher aspirants. The model and its practical application are discussed comparing with the practicing models employed in disseminating the subject matter knowledge and the present-day Teacher Education Programmes.

INTRODUCTION

A person who aspires to become a teacher must have good Content/Subject Knowledge (SK) and at the same time, s/he should be proficient in Pedagogical Content Knowledge (PCK) - the ability to communicate subject matter to students effectively. Lee Shulman first coined the concept of Pedagogical Content Knowledge (PCK) in science education in the mid-1980s (Shulman, 1986, 1987). It has attracted the attention of researchers in education, but remains least recognized largely by practicing science teachers.

New methods (e.g., heuristic, project and problem-oriented) as well as novel technologies (smart classrooms, blended learning etc.) have been introduced in the field of education, but it is lacking behind in realizing its purpose, which is to develop skills to stimulate experience in the taught, under an environment created by design and not by default. Its scope has broadened with the reforms in the area, mainly, the implementation of the Integrated Teacher Education Programmes (ITEPs) and its objectives have become focused during the last thirty-five years, but teacher education could not realize its objectives entirely (Kind, 2009).

For centuries, the traditional in-person, classroom-based teaching and learning, technically known as the "didactic approach" has been the ubiquitous delivery method of knowledge to the students. Moreover, it is still practiced worldwide as the major method of dissemination of information on various platforms. In the past three and a half decades, various models have been proposed and are being implemented to move away from this method.

The problem-based learning (PBL) (Barrows & Tamblyn, 1980; PBL), process-oriented guided inquiry learning (POGIL) (Farrell et al., 1999; Carneiro et al., 2016; POGIL), and peer-led team learning (PLTL) (Gosser et al., 2006; PLTL) have received wide attention, as they are student-centered active-learning pedagogical strategies in core subjects. These models have proven to be successful albeit with their limitations depending on the disciplines adopted, social context as well as a variety of academic settings in which they are implemented. The main aim of all these models is to improve the learning skills of the students, tailored to their responses and in the end, expecting a better understanding of the subject. Needless to say, the implementation of these models requires the continuous tracking of student progress over a longer period and requires various resources depending on the academic and social conditions.

In the implementation of all of the aforementioned models, the execution is carried out mainly by the subject teacher who has undergone full (Teacher Education Programme), partial (some crash courses in pedagogy) or in some cases no formal training in pedagogy. This results in either overestimation or underestimation of the effectiveness of the model implemented, leading to ambiguity. Considering these aspects, a model called Coupled Class Model (CCM) has been proposed that addresses some of the pitfalls of the Teacher Education Programmes that are being practiced. Coupled Class Model (CCM), addresses some issues related to the SK and PCK delivery to the students taking the Teacher Education Programmes.

The Teacher Education Programmes (TEPs) in India are segregated as Integrated Teacher Education (ITE), Bachelor of Education (B. Ed.), Master of Education (M. Ed.), and Diploma in Education (D.Ed.). The National Commission on Teachers (1983-85) recommended five-year integrated programmes with internship (NCT, 1983-85). The National Advisory Committee on Learning without Burden has also thrown light on the need for qualitative reform of Teacher Education Programmes (NACLB, 1993). The government of India has put forth the 'National Education Policy, NEP 2020' for enhancing the standard of current educational programmes. The details are available on the website of the Ministry of Education, India (NEP, 2020). Particularly, teacher education programmes have been reformed with the aim of professionalizing and thereby improving the standards of school education. NEP 2020 stresses that aspiring teachers require quality training in content as well as pedagogy. For this, teacher education will gradually be moved into multidisciplinary colleges and universities. The policy also proposes to make the four-year integrated teacher education programme mandatory for teacher aspirants (NEP 2020, paragraph 5.23).

This work proposes and aims at making PCK more explicit by integrating it in the Teacher Education Programmes that may help novices adjust to teaching, as well as aid them in developing more reflective practices, which are effective. This integration of content and pedagogical knowledge is highlighted in the Position Paper on Teacher Education for Curriculum Renewal as, *'knowledge in TE comprises various kinds e.g., conceptual, technical, professional etc.'* (National Focus Group Position Paper 2.4). In the following section, CCM is presented along with its advantages, disadvantages, framework and preliminary results of its implementation.

COUPLED CLASS MODEL (CCM)

Coupled class model is a different approach for scaffolding aspiring teachers and is applicable for ITEPs like B.Sc.B.Ed., M.Sc.Ed. and B.A.B.Ed. exclusively. This model considers a classroom scenario wherein two teachers (one handling the subject, for example, science, and one, education) teach in tandem[6].

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[6] It is to be noted that one may be of the impression that the 'coupled class model' is similar to the 'parallel teaching in inclusive education' (Friend and Cook, 1996). The latter addresses school education whereas the former is related to the Teacher Education Programmes for aspiring teachers.

The two teachers discuss the topic to be rendered well in advance so that the education teacher can work on the pedagogical aspects of the same. Once the best suitable pedagogical strategies are agreed upon, the science teacher can flick through them and incorporate those methods in the instruction to the optimum level. During instruction, while the science teacher delivers the content, the education teacher can ponder upon the efficient teaching strategies adopted, which s/he would have been listed on a whiteboard or an LCD projector. The class advances in a similar way and while concluding, there would be a discussion or reflective session to clear student teachers' queries in both the domains as well as to refine the teacher educators' understanding.

The lesson is primarily divided into two sessions:

i) *Session 1:* The first session (about 35 - 40 minutes) will be handled by the subject teacher discussing the subject using traditional methods and available technological resources or ICT tools implementing the pedagogical aspects discussed with the pedagogy teacher.

ii) *Session 2:* In the second session (about 35 - 40 minutes, after a break in between), the pedagogy teacher and subject teacher discuss the particulars related to PCK and SK parts of the presented topic. The remaining time of the session will be open to discussion for clarification of doubts or misconceptions, juxtaposition of associated reflections and collection of feedback from the students. An assignment will be given to the students for further enhancement of their knowledge on the topic discussed.

The introduction of the CCM Model into current ITEPs needs to be carefully analyzed. There are two different ITEPs namely, B.Sc.B.Ed. and M.Sc.Ed. which are having duration 4 and 6 years respectively. The curriculum for M.Sc.Ed. is the same as that for B.Sc.B.Ed. for the first four years of the course. In addition to the School Attachment Programmes conducted at the end of each semester, there are Internship Programmes during the fourth (seventh semester of both B.Sc.B.Ed. and M.Sc.Ed.) and sixth (eleventh semester of M.Sc.Ed.) years of the courses. This will be organized respectively in selected upper primary and higher secondary schools in India where the student trainees will have a specialized practice in teaching experience. Hence, the induction of this model would be preferable well before the Internship Programmes so as to ensure better intern performances as they would more efficiently be trained for practice teaching on the actually integrated foundation of both content and pedagogical knowledge. Considering this aspect, the induction of the CCM Model during the third year (fifth and sixth semesters) of the ITEPs is proposed for the smooth and efficient advancement of the course of study. As in pre-service teacher training, this model can be equally employed during in-service teacher training programmes as it significantly contributes to update, upgrade, rejuvenate and revitalize the professional competencies of teachers.

The coupled class model with such an integrated design has many benefits:

1. Focuses on basic pedagogical and scientific skills, content, and application
2. Provides a deeper, more relatable and authentic understanding of content as well as its delivery, which is the ultimate aim of teacher education
3. Widens the horizons of professional competency by consistently exposing student teachers to global and innovative instructional strategies
4. Creates a positive and collaborative learning environment
5. Breaks traditional lecture ennui

6. Keeps away the problems that can pop up in a single-teacher class like monotony, lack of divergent ideas or strategies and inability to address different needs of the students.
7. Saves time as there is no need for separate education and science classes.
8. Condenses the workload on teachers as they work collaboratively and efficiently
9. Intrinsically motivates student teachers to succeed in real life

On the other hand, there are some challenges to this model as well. They are:

1. The efficient conduct of such a class demands effective planning among the teachers, which in turn expends time.
2. Teachers may be reluctant to collaborate, put time and effort into changing what they already do in the classroom and implement something different.
3. Like-mindedness of the teachers in coordinating schedules and agreeing on ideas is often a difficult task.
4. Student teachers' cooperation is significant as they should be willing and determined in embracing this model.
5. The effective implementation of any endeavour requires the flawless organization and efficient functioning of its components.

The CCM is built on mainly five significant pillars (Fig.1) which include:

1. **Student:** Student is the center of the CCM similar to other models. The primary goal of any educational model is to improve the standards of education, especially, the quality of primary education where teachers trained from Teacher Education Programmes play a dominant role. In particular, the learner and his/her learning capabilities are shaped during the training. To accomplish this, the learner has to be associated with the remaining four elements - teacher, SK and PCK, technology and institution, which in turn are also interrelated to each other and have their own characteristics.
2. **Teacher:** The teacher certainly plays a major role in imparting the knowledge and wisdom. S/He makes the learner to master the nuances of teaching, trains the learners to the needs of the society and equips them to be competent and confident. In order to achieve the above goal, teachers have to adapt themselves to the circumstances and employ pedagogical strategies that are appropriate in engaging the students (in addition to the subject matter). To be more productive and effective to the societal requirements of the 21st century and to cater to the needs of the students, they have to keep the students abreast by updating themselves to the developments in their subject areas, the educational practices around the world and integrating technology in the educational system. Moreover, they need to impart moral and value education.
3. **SK and PCK:** SK is still the primary focus of learning, and PCK, the delivery method, influences to a greater extent the process of mastering the subject. In the Teacher Education Programmes, both SK and PCK equally play an important role, which are associated with the learner, teacher, technology and institution. The SK should be reinvented by including the latest developments in the topics discussed without diluting or compromising on the quality. Accordingly, the PCK should be envisaged to convey the SK. The SK integrated with technology also gives an opportunity for deep learning of the content through interactive, multimedia materials and group learning.

4. **Technology:** In the last fifteen years, technology has seeped into every nook and corner of all societies changing the lives of the people. Students are not left behind to that and have great benefits with the accessibility to splendid resources online. However, they are also prone to information that is conceptually wrong and are hence failing to distinguish between the 'right' and 'wrong', 'good' and 'bad'; to filter out the relevant content to their needs. Here again, teacher plays a crucial role in guiding them (provided s/he is technologically competent).

5. **Institution:** Last but not the least, institutional support is an essential ingredient for fulfilling the above requirements for a progressive, modern, educated and civilized society. In addition to providing the facilities such as classrooms, laboratories and library, technological infrastructure need to be provided. Furthermore, institution creates a platform/ambience for collaborative learning; fosters creativity, critical analysis, enhancement of skills and time management and supports teachers to develop effective teaching and learning strategies leading to professional success and growth. This ultimately helps students improve their knowledge of the subject, associated pedagogical knowledge and experience technological innovations implying overall development.

The primary goal of any educational model is to improve the standards of education. All the aforementioned components have to be interrelated to each other and should have their own characteristics. The relationship between them is dynamic and integrated. Thus, CCM contemplates an integrated plan utilizing the best of what both SK and PCK have to offer.

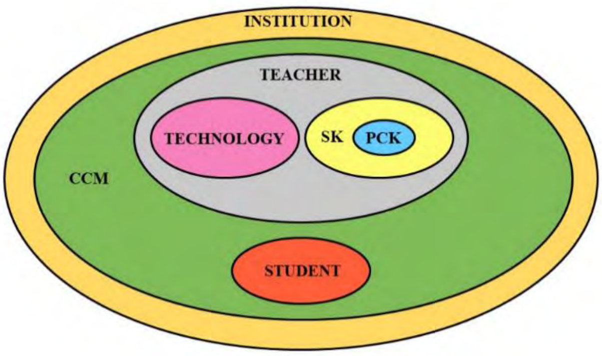

Figure 1. The framework of the coupled class model (CCM) with five building blocks.

CCM comparison with PBL, PLTL and POGIL

The salient features of the CCM compared to PBL, PLTL and POGIL models are:

1. CCM addresses both SK and PCK simultaneously.
2. *Purpose*: Brings new trends in teaching methodology with particular emphasis on Pedagogical Content Knowledge (PCK) and addresses the issues associated with the methods employed in present-day teaching practices followed in colleges, specifically, Teacher Education Institutes.

Parameter	CCM	PBL	PLTL	POGIL
SK	Yes	Yes	Yes	Yes

Preparation	Both SK and PCK instructors prepare	SK instructor	SK instructor	SK instructor
PCK	Yes	-	-	-
Nature of Session 1	Lecture by SK instructor (~40 minutes)	Collaborative discussion among students to solve a problem	Lecture	Lecture
Nature of Session 2	Collaborative discussion by both PCK and SK instructors (~40 minutes)	-	-	-
Presentation	1. SK instructor (session 1) 2. PCK instructor (session 2)	SK instructor	SK instructor	SK instructor
Concept development	From lectures of instructors, discussions; reinforces the concepts through simulated teaching sessions	Problems drive concept discovery on a need-to-know basis	Probe and apply concepts introduced in text, lecture, and homework	Through group work, and reinforce with application
References	Prescribed subject and educational textbooks, primary literature, internet and expert opinions	Primary literature, reworked stories of case-based issues	Published workbooks, textbooks, problem sets adapted from workbooks	References
Discussion	PCK and SK aspects of the topic by the two teachers and students	SK only	SK only	SK only
Homework	Students individually gather information for addressing 'learning issues,' and prepare to share the findings	Students conduct subject researches	Homework from lecture classes	Exercises and problems related to group
Grading/ Assessment	i)Formative assessment (from attendance, preparation, attitude, active participation in lectures and discussions and performance in simulated teaching sessions) ii)Summative assessment (Involve only individual work)	i)Major effect on course grade from attendance, participation, preparation ii)Tests include group efforts	i)Workshop attendance and participation usually does not have a direct effect on grade ii)Tests involve only individual work	i)Some credit usually assigned for group work ii)Tests involve only individual work

Table 1: Comparison of various parameters: CCM with PBL, PLTL and POGIL models.

Some of the limitations of the above models could be tackled with the implementation of the CCM proposed in this work. It is complementary to the existing pedagogical practices implemented by various practitioners of education.

Preliminary implications of implementation of CCM

The efficacy of the CCM was experimented by conducting online classes employing the model, checking student understanding and collecting student feedback. The model was executed by two pre-service teachers (as lesson demonstrations). The selected target group consisted of the B.Sc.B.Ed. (PCM and CBZ) and M.Sc.Ed. (PCM) students (seventh semester, 2021-22) of RIE Mysuru. The execution was prior to the student internship programmes as proposed (see section 'Coupled Class Model')[7]. Student feedback was very encouraging, which reflected in their comments. Some of the important comments are presented here.

> 'It was really good to attend this preparatory class online as it helps to plan and organize lessons more effectively.'

> 'Session 2 helped to link the pedagogical theories to practical application as it highlighted the strategies and its benefits which would help us during the upcoming internship.'

Further, the students were asked to attempt a pre-demonstration questionnaire before the execution of the CCM lessons, which would facilitate the analysis of the presentation. A post-demonstration questionnaire would also be given after the model lessons. The authors are working on the analysis of the student performance in attempting these questionnaires and their responses to the model. The authors would like to present further details in connection with the execution of CCM and its comparison with other PCK models (Kind 2009) as a future endeavour.

Difficulties during facilitation:

- The model requires careful planning before and consistent follow-up after each session from both the teachers, which may not be always possible.
- Irrespective of the nature or target group of a subject, the instructional strategies are generalizable and can be applied to both school and higher education. At the same time, as the subject, needs and level of the learners vary, the strategies should also be tuned specifically.
- Educators must also take care that the subject knowledge is not compromised for pedagogy practice.

CONCLUSION

To summarize, coupled class model (CCM) addresses the issues associated with present-day teaching practices followed in colleges, specifically, Teacher Education Institutes. It surpasses the traditional methods of teaching and provides an effective understanding of subject knowledge and pedagogical content knowledge. The implementation of CCM in a classroom, the challenges faced during the same and the student feedback are presented. The analysis of the results of pre- and post-implementation questionnaires will be presented in future work. Through the active institutional and faculty commitment of time, resources, careful and extensive planning, this model can enhance the teaching and learning experiences of both students and faculty and fulfil the purposes of education helping the participants integrate two disparate disciplines and perspectives.

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[7] The demonstration videos are available with authors and the web link will be provided on reasonable request.

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CLIMATE CHANGE IN ENVIRONMENTAL EDUCATION IN MIDDLE-SCHOOLS OVER WEST BENGAL: STATUS AND PERCEPTION EVALUATION

Arindam Roy[1,a,!]

[1]École polytechnique fédérale de Lausanne, Rte Cantonale, Switzerland

[a]they/them/their

!arindam.safe@gmail.com

Climate change perceptions of the middle-school students (n = 230) were evaluated and the connection between climate change in school textbooks and perception was explored for middle school students in West Bengal. It was observed that the topic of climate change was first introduced in class VII and it disappear from the syllabus in class VIII. The climate change perception was overall improved in class VII and VIII as compared to class VI, however, no significant difference in student perception was found between class VII and VII. Allthough students, irrespective of classes, can able to identify increasing local extreme changes due to climate change. The students are unable to connect between climate change and its role to increase extreme events and loss of livelihood. The textbook describes the global impact of climate change in detail whereas the local effect of climate change on livelihood and the ecology-economy nexus has not been mentioned at all. Overall, the study indicates that climate change remains an unimportant part of the middle-school syllabus and requires immediate attention.

INTRODUCTION

Climate change is the single most important reason behind the existential crisis of humans and biodiversity in the present time (Zhongming et al., 2019 – IPCC report). Gradually increasing temperature, sea-level and weather extremities are creating inequity, death and economic loss all across the globe (Jones, 2001; Nelson et al., 2009). At present, India is not only one of the climate-vulnerable countries but also a major emitter of greenhouse gas. The eastern Indian state of West Bengal, is considered the most climate-vulnerable state due to its proximity to the Bay of Bengal, Himalayas, Chota Nagpur Plateau and Gangetic flood plain (Ghosh and Ghosal, 2009). The geographical diversity of the state is associated with the risk of extreme events like cyclones, floods, landslides, heat waves, etc. (Sharma and Chauhan, 2011).

The climate change perception is a piece of important information to access the awareness, adaptation potential and vulnerability (Yu et al., 2013). The perception of climate change among school students is well-studied across the globe (Ochieng & Koske, 2013; Kim. 2015; Ojala. 2015), however, to the best of our knowledge none of these studies are conducted of West Bengal. Middle school is an important step for the development of students when they prepare themselves for the future (George et al., 1992). Therefore, it is important to access the perception of middle school students on relevant topics like climate change. In this study, I evaluate the environmental education syllabus and textbook of schools affiliated with the West Bengal Board of Secondary Education and further investigate the perception on climate change of the middle school student studying under the same board.

Climate change in an environmental education textbook

The climate change relevant part of Environmental Sciences has been discussed in the section. In class VI, the textbook barely covers any climate change-related topics. Although, fossil fuel and its usage, concept of biodiversity and basic recycling procedures were described. Unsustainable consumption of natural resources was superficially described through incremental usage of coal and fossil fuel. However, the impact of fossil fuel emission modulating global climate was not mentioned. Man-made natural disasters and bio-magnification were briefly outlined. All these topics were discussed very briefly (1-2 lines) and do not intend to highlight the contribution of man-made alternation of the natural balance of the environment.

The class VII Environmental Science book uses the word "Climate Change" for the very first time and represents different types of extreme events pictorially. The increasing temperature has been mentioned briefly. An interesting exercise was given to the students where they have to fill out a form while talking to elderly persons for finding out the local changes in climate patterns. The next section very briefly describes the sources of Green House Gases followed by a detailed account of the impact of climate change in the recent past; floods, landslides, droughts, coral reef bleaching over Indian states. The role of trees in the ecosystem and human-induced biodiversity loss due to changing climate is being well documented and moreover, the Indian scenario is well represented.

The over-population and unprecedented usage of fossil fuels have been introduced in class VIII. Although the relationship between fossil fuel emission, atmospheric CO_2 and climate change is not explored. The technology behind solar and other alternative energy options is briefly described. Superficial connections between greenhouse gasses and global temperature rising are made. The importance of forest, its benefits and risks and conservation of wild animals are described in a detailed manner. The summary of the syllabus for the three middle-school classes is summarized in Table 1.

Class	Climate change related topic	Relevance
VI	Biodiversity, waste and recycling, Man-made flood, Biomagnification of pesticides.	Definition-based topic introduction. Topics are described scattered manner. Consequences are not mentioned.
VII	Climate change cause, impact, extreme events, water cycle, deforestation, heat island, biodiversity loss.	Descriptive climate change impact. Climate change causes are not described. Local issues are briefly highlighted. Interactive exercise for local impact.
VIII	Over-population, over usage of fossil fuel, renewable energy	No chapter addressing climate change. Brief introduction on renewable energy. Implications of energy crisis not mentioned.

Table 1: Climate change topics covered by different classes

The overall environmental study syllabus in middle school in West Bengal indicates inadequate description regarding the local impact of climate change. With six different eco-geographical regions, West Bengal is the most climate-vulnerable state in India and the incorporation of recent changes in climatic patterns in those areas could really help to visualize the impact for the students. The reason behind climate change and the relationship between global greenhouse gas concentration and increment of global average temperature is not described at all. Surprisingly, climate change was introduced in class VII and the complexity of the issue was not discussed at all in class VIII. The discontinuation of climate change education in the higher class can be crucial as this might lead to developing a belief on climate change as a “less important topic”. Also, the present climate change is absolutely caused by human-emitted greenhouse gas and this statement has not been mentioned exclusively. The energy-water-food nexus and economy-ecology balance have not been described at all. Moreover, lack of information about climate-adaptive livelihood, misinformation regarding climate change, climate justice and sectoral contribution of climate change are noted.

CLIMATE CHANGE PERCEPTION STUDY: METHODS

To evaluate the perception about climate change cause, effect, local impact and climate justice, I conducted a survey among middle school students (n=181, Table 2) in government schools over three climate-vulnerable regions of West Bengal; Sundarbans, Midnapur and Murshidabad. Sundarbans is the world's biggest mangrove delta and being struck by multiple cyclones in recent years which leads to saltwater inundation in freshwater ponds and fields (Ali et al, 2020). Located in the arid region of Chota Nagpur Plateau, Midnapur is a place where extreme temperature events and heat waves are increasing in recent years. Heavy rainfall and dam failure in Murshidabad are causing floods almost every year in recent times (Mollah, 2020). All students in these three schools belong to the rural agrarian community and are from low-income backgrounds. I also performed a similar survey in a governmental school in Kolkata (n=49) where students are mostly from middle-income to high-income families. The objectives of the present study are to a) Understand the climate change perception of the middle school students in climate-vulnerable regions of West Bengal; b) Effect of the school environmental education on climate change perception; c) Spatial variation of climate change perception among the students.

Variable	Place	Frequency
Gender (Male)	Urban	51%
	Rural	53%
Age (Mean±SD) in years	Urban	12.2±0.9
	Rural	12.7±1.1
Primary occupation of parents	Urban	Service (62%)
	Rural	Farming (79%)
Household monthly income (Mode)	Urban	>45000 INR
	Rural	<10000 INR
Primary source of drinking water	Urban	RO+UV (67%)
	Rural	Deep tube well (71%)

Table 2: Brief description of variables among the survey participants

Climate change perception in different classes

The climate change perception was evaluated through a series of questions among students of all middle school classes (Fig 1). As climate change was introduced in class VII, the majority of the class VI students either do not know about climate change (39%) or believe climate change is a distant phenomenon that will occur in the future. Although the proportion who believes in climate change as a present crisis improves for class VII and VIII, however, a significant portion of the students for these two classes (25% and 30%) still see climate change as a distant phenomenon. A substantial proportion of students of class VII (26%) and VIII (31%)

believe in the natural causes of climate change even after the introduction of climate change in the syllabus. The students were able to identify the increasing weather extremes in their locality but a significant proportion (32% to 72%) failed to connect the weather extremities with climate change. The connection between climate change and the livelihood of families is not at all precepted well as a large proportion of students either don't know or don't believe that climate change is impacting their parent's livelihood.

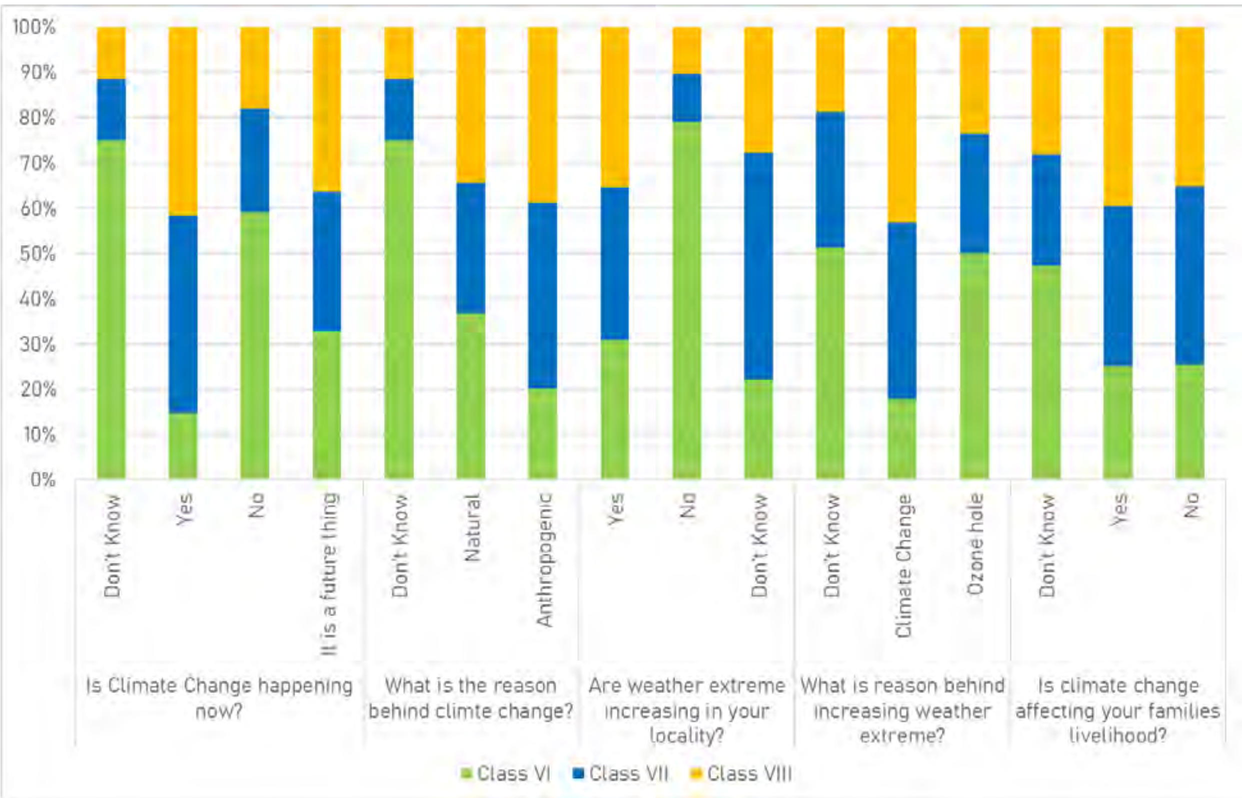

Fig 1: Climate change perception among different middle-school classes

Clearly, a better perception of climate change was noted after the introduction of the topic in the school books. Class VII and Class VIII students are more concerned about climate change. Interestingly the concerning percentage of students does not vary much for classes VII and VIII which is possibly due to the discontinuation of climate change in the syllabus in class VIII. The students are unable to connect climate change with extreme weather events or livelihood and this indicates that the syllabus requires modifications and incorporation of regional impacts of climate change.

Climate change perception: framing the right question

Although in the perception study, questions related to climate change have been asked to the students, these questions are very generic. To understand the "true" perception among the students, I have modified the questionnaire and ask questions more relevant to their locality to a subset of the students (n = 98). For example, the students from Sundarbans (adjacent to the coast of Bay of Bengal) were asked "Is cyclones affecting their livelihood by salt water inundation in cropland and ponds?". The students from Midnapur and Murshidabad were asked "Do you feel stronger heatwaves in summer leads to water crisis and crop failure?" and "Is flooding reducing earning of your family and damage your field and home?". In addition, students were asked to send a narrative anonymously related to the impact of extreme weather events in their livelihood.

> During Amphan (Cyclone), we lost three cattle and eight ducks. We took shelter in the cyclone center. After few days, when we came to our home, we find it damaged. We could not able to move our livestock and most of them died. The land is now filled with salt water and can't be used for agriculture. My father and brothers are now at Kolkata working on a daily wage.
>
> – A class VI student of Sundarbans
>
> This year, tube-wells and wells became dry in mid-summer and we went to collect water from the jhoras (small aquifers). But when the jhoras got dried, we had to walk miles before we get water for home. Fields became dry and my father goes to city every day for finding works.
>
> – A student of class VI of Midnapore

The response from the class VI students were completely opposite to the findings from the generic questionnaire about climate change. We compare the climate change perception from the modified questionnaire and narrative, and no significant difference in response was found between all three middle-school classes. It was observed that most of the students in Class VI, VII and VII has similar perception on the impact of climate change (94% - 97%). Irrespective of classes, the narrative from students are very advance as they talk about climate refugee, vulnerability and livelihood damage (not the terminology).

Limitation of conventional "One size fits all" climate change syllabus

The results from the present study indicates that the climate-vulnerable students can able to understand the impact of climate change, although it has not been introduced in their syllabus. The connection between green-house gas emission and emergence of extreme events are not well understood by the students. The link between food, water and livelihood security and how it is impacted by climate change is not very clear to the student. The local impacts of climate change are not discussed in their text books and therefore it is difficult for them to draw the connection between green house gas emission and crop failure.

CONCLUSIONS

The present work evaluated climate change education in the middle school of West Bengals followed by a perception study on climate change. Climate change is introduced in class VII and no further follow-up was observed for higher class; i.e. Class VIII. This directly impacts the student perception of climate change as the class VII and class VIII students show similar perception. However, a different result has been found by modifying the questionnaire. It was observed that the students, irrespective of classes, are well aware of local changes due to climate change however, they cannot relate the local impact to the global greenhouse gas emission phenomena. The results from the present study clearly indicate the insufficiency of climate change education and call for incorporating more climate change-related education material in middle school.

Acknowledgement

I would like to acknowledge my gratitude towards several individuals who have discussed the topic with me and help during the survey. However, the name and identity remain undisclosed due to the double-masked review process. I would like to thank the anonymous referee whose suggestion made me look back to my data and I added valuable input.

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EFFECTIVENESS OF EXPERIENTIAL LEARNING FOR THE TOPIC OF LENGTH MEASUREMENTS IN GRADE 6

Anusha Bhat[1, a, *] and Prathik Cherian J[1, b, #]

[1]Dept. of Physics, Prayoga Institute of Education Research, Bengaluru, India

[a]she/her/hers, [b]he/him/his

[*]anushabhat@prayoga.org.in, [#]prathik@prayoga.org.in

This study sought to investigate the effectiveness of implementing experiential learning using hands-on activities for the topic of 'Length Measurements' in CBSE 6th grade. A quasi-experimental research design with a post-test was used for this study in a CBSE school in Bengaluru, India. The experimental group consisted of 62 students and the topic was taught using activity-based experiential learning pedagogical approach. The control group consisted of 95 students who were instructed in the traditional method. Upon completion of the chapter, both groups were administered a post-test designed to assess the learning outcomes of the topic, especially the conceptual and procedural understanding of the students. The analysis of the results of the post-test indicate that the experiential learning pedagogy was indeed more effective than the traditional method of instruction.

INTRODUCTION

Experiential learning has long since established itself as one of the most commonly accepted learner-centric pedagogies to replace the traditional teacher-centric instruction methods. Experiential learning is based on the constructivist theory of learning and places the emphasis on the learner to construct the knowledge with the aid of experiences in the form of hands-on activities, games, discussions, role-playing etc (Kolb, 2015).

Over the past couple of decades, the teaching and learning of STEM subjects using active learning and experiential learning with hands-on activities has seen a significant rise at the school as well as college levels (Bot et al., 2005; Threeton & Kim, 2021). The recently unveiled National Education Policy 2020 of India mandates that experiential learning should be adopted for all subjects at all levels of schooling (National Education Policy, 2020).

The usage of hands-on activities for teaching science has been well explored in literature (Flick, 1993; Haury & Rillero, 1994). This 'learning by doing' pedagogical approach to science has been seen to enhance student's conceptual understanding of the science topics (Satterthwait, 2010; Sadi & Cakiroglu, 2011). Experiential learning has also been seen to impact student attitude and motivation towards STEM subjects (Garvin & Ramsier, 2003; Weinberg et al., 2011).

In the next section, we explain the methodology of our study and its implementation in detail, and in the subsequent section we present the data analysis, and in the final section, we draw our conclusions.

METHODOLOGY AND LITERATURE REVIEW

For our study, the research design was chosen to be quasi-experimental design with post-test only (Krishnan, 2019). A quasi-experimental design was necessary as it was not possible to randomly assign the students into the control and experimental groups – we had to work with the pre-existing 6th grade sections as they were. The chosen school in urban Bengaluru had a homogenous set of students from similar socio-economic backgrounds, and had both CBSE (2 sections) and State (3 sections) syllabi in 6th grade. The two CBSE sections (comprising of 62 students in total) formed the experimental group for whom the experiential learning was implemented. Since the Karnataka State syllabus follows the NCERT science textbook, the 3 state syllabus sections (comprising of 95 students in total) were chosen as the control group. The instruction for the control group in traditional method was handled by the regular science teachers of the school.

We chose ‘Length Measurement’ from 6th grade CBSE Science syllabus as the topic of implementation. This topic was chosen on the basis of previously noticing that students were struggling to grasp the concepts involved such as units of length, conversion of measurement units etc. It had also been noted previously that a significant fraction of students failed to comfortably measure lengths using rulers. A subsequently conducted literature survey revealed that there have been several research studies delving into these aspects which had similar observations. Students’ misconceptions as well as their difficulties with using rulers and understanding units and unit conversions have been explored and reported (Hiebert, 1984; Bragg & Outherd, 2004; Levine et al., 2009; Christie, 2012; Drake, 2014).

IMPLEMENTATION

A post-test consisting of 6 short-answer questions (including MCQs) was designed with the main objective of assessing the student understanding – both conceptual (length as distance between two points, units, unit conversions etc) and procedural (how to measure length) – of the topics learnt. The questions were independently reviewed as appropriate for 6th grade CBSE and State syllabus students for this chapter. Table 1 describes what concept each question was designed to assess. After the chapter was completed, the post-test was administered to both groups and a comparative analysis was done.

Concept Assessed	**Question Nos.**
Using rulers to measure a length interval.	1, 3, 5
Unit conversion between millimetre, centimetre and metre values.	2, 4
Choosing measuring instruments appropriate for the situations.	6

Table 1: Concepts assessed by the post-test.

The main activity for the experimental group was to introduce units of length measurements and the idea of unit conversions. It was designed by taking the activity mentioned by Christie (2012) as a starting point. This activity was divided into two parts and required two sessions of 40 minutes each. Students are divided into groups of 5 and each group were given some colored paper strips. These paper strips were of 3 different colors, each color with a specific length. These strips are shown in Figure 1 below. The pink strip was the longest and was 8 cm in length, the blue strip was 4 cm in length and the black strip was the smallest was 2 cm long.

In the first part of the activity, students were provided a sheet printed with 6 lines oriented in different directions. The length of each of these lines fit into some combinations of the given strips. The objective of this activity was to make students appreciate the necessity of smaller and larger standards (units) for length measurements. Students were asked to measure the length of the lines using those strips and write the combination of strips they used for the measurement.

Most of the students could identify the different combinations of the strips, but a few of them struggled while taking the measurement of the lines oriented other than in horizontal or vertical directions and were placing the strips one above the other. The concept of different standards used in measurements (later mentioned as units) were conveyed using the different colored strips.

In the second part of the activity a sheet with a single line (of length 16 cm) printed was given to the students. They were asked to measure the length of the line, but this time they were to use only one of the three types of strips for measuring the length. Students were then able to identify that the length of the printed line can be measured using integral multiples of each colored strip. They were able to appreciate that the number of strips required to measure varied with the type of strip used (i.e. standard) even though the length of the printed line did not change.

Figure 1: Paper strips used for the activity (pink – 8 cm, blue – 4 cm, black – 2 cm).

After this activity, a demonstration involving a meter scale was done. By counting the number of centimetre and millimetre divisions, they inferred that meter is a larger unit compared to centimetre and millimetre, and centimetre is larger than millimetre. Further, they identified that 1 m = 100 cm, 1 cm = 10 mm, and 1 m = 1000 mm.

DATA ANALYSIS

The post-test was administered in each of the control and experimental groups upon completion of the instruction of the chapter. The final sample size of the control group was 87 and experimental group was 54 due to several absentee students on the day of the post-test. The student responses to the post-test were evaluated by one of the authors using a simple rubric which when applicable separately took into account the conceptual and mathematical aspects of the question. To analyse the student performance in terms conceptual understanding, the percentage of students identifying and applying the concepts correctly for each question in the post-test has been plotted below in Figure 2. It was seen that the experimental group outperformed the control group in all the 6 questions i.e., a higher percentage of students were able to answer the question in each of the questions.

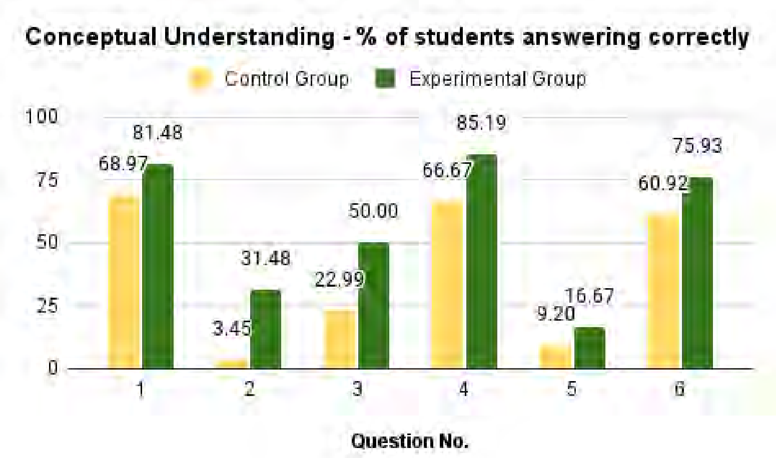

Figure 2: Comparison of conceptual understanding in the post-test.

The experimental group of students exhibited better conceptual understanding of length measurements using rulers as is evident by comparing the percentage of correct responses for questions 1, 3 and 5. For questions 2 and 4 which were problems involving unit conversions and once more, it can be seen that the experimental group far outperformed the control group.

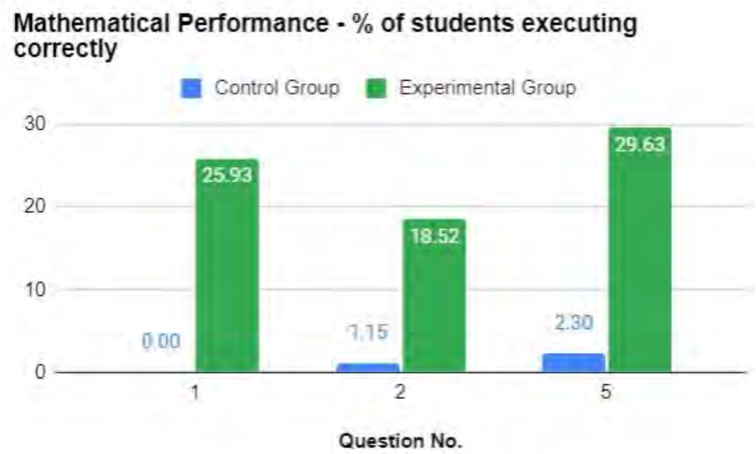

Figure 3: Comparison of mathematical performance in the post-test.

In Figure 3, the mathematical performance of the control and experimental groups is compared in terms of the percentage of students executing the mathematical operations correctly in questions where mathematical proficiency was required (questions 1, 2 and 5). This includes proficiency of basic arithmetic operations such as subtraction, multiplication etc. Both sets of students were seen to be struggling quite a lot in these aspects. Many students were identified to be struggling with multiplication and decimals. However, the experimental group were seen to do significantly better than the control group of students.

Another statistical yardstick was to compare the average normalized post-test scores for both of the groups. It was seen that the average normalized score for the control group was 2.48 whereas the same for the experimental group was 4.79. In other words, the experimental group outperformed the control group score by 93%.

CONCLUSIONS

Based on the analysis of the post-test data, it was seen that the experimental group with the experiential learning intervention showed higher performance both in terms of a higher proportion of students being able to answer the questions correctly as well as higher normalized scores. However, we should consider one important caveat before making a conclusion that it was solely the intervention which caused this higher performance by the experimental group. The fact that a post-test only quasi-experimental design was used means that there is a possibility that the two groups were not equivalent to begin with and that the experimental group outdoes the control group regardless of the intervention.

However, the mathematical performance leaves much to be desired. A plausible explanation could be the impact of the pandemic and the disruption it has caused over the past two years and the ineffectiveness of a presentation-based online instruction for mathematics especially.

Overall, the results were still encouraging enough and points to the fact that experiential learning with activities can be a an effective and engaging pedagogical approach to teach science concepts to middle school children. More teachers should attempt to implement experiential learning and thereby make the learning process more coherent and meaningful for the students.

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ENRICHING MICRO-TEACHING SKILLS WITH TSPCK FRAMEWORK IN PRE-SERVICE TEACHER EDUCATION

Narendra D Deshmukh [1, a,*] and Eunice Nyamupangedengu [2,b,#]

[1]Homi Bhabha Centre for Science Education, TIFR, Mumbai, India

[2]Marang Centre for Mathematics and Science Education, School of Education, Wits University, Johannesburg, South Africa.

[a]he/him/his, [b]she/her/hers

*ndd@hbcse.tifr.res.in ,#eunice.nyamupangedengu@wits.ac.za

Micro-teaching is a teaching technique especially used in teachers' pre-service education to systematically train by allowing them to experiment with main teacher behaviors. Topic Specific Pedagogical Content Knowledge (TSPCK) is the basis by which knowledge of the subject matter of a particular topic is conveyed to pupils. This includes pupils' prior knowledge, curricular saliency, what makes a topic easy or difficult to teach, representations including analogies and metaphor, and teaching strategies.

This research aims to understand the pre-service teachers' perceptions and implementation of TSPCK in practice lesson plans and its presentation to facilitate an effective teaching-learning process. A one-month course on (TSPCK) was conducted for 81 pre-service teacher educators who had enrolled in a Teaching Practice course at a faculty of education. Data was collected using practice lesson plans (81), online presentation using a Single Point Rubric (36) and from semi-structured interviews of pre-service teachers (10). The researchers used thematic analysis to analyze the data. The findings of the research revealed that pre-service teachers are aware of the importance of planning lessons; however, they found some difficulties in using the TSPCK framework due to inexperience of teaching in an actual classroom. Many of the components are based on teaching experience which can't be expected from pre-service teachers. Also, the TSPCK components helped the pre-service teachers increase their confidence and acquainted them with prior knowledge about PSK and also their students' prior knowledge. The study also reveals that training in TSPCK components will help the teachers in their professional growth. As their teaching experience will increase, they will acquire more understanding in designing lesson plans and its implementation. The results suggest that opportunities should be created for pre-service teachers to get acquainted with TSPCK during their lesson planning and practice. Further investigation will help researchers to understand more about how one can help teachers to develop micro-teaching skills using TSPCK to plan and implement their lessons effectively.

Keywords: *TSPCK Framework, Lesson plan, Micro-teaching, pre-service teacher education, Single Point Rubric*

INTRODUCTION

Micro Teaching is a way of monitoring, developing and refining pre-service teacher teaching style by getting feedback from peers and educators in a controlled setting which helps them to assess their own teaching style, gives an opportunity to improve it and stand in front of school students with confidence in actual classroom-situations. The concept behind micro-teaching is to combine theory with practice. Pre-service teachers try their theory-related concepts in practical settings with their peers and educators. It gives pre-service teachers the opportunity to reflect on their own performance and receive feedback to develop their own skills as a teacher and to prepare them to face challenges and opportunities of real classroom settings. During practice, pre-service teachers learn various micro-teaching skills, such as, i) introduction skill; ii) skill of probing questions; iii) skill of explanation; iv) skill of stimulus variation; v) skill of Black-board writing; and vi) skill of achieving closure. Micro-teaching is a cyclic process containing the six steps: plan, teach, feedback, re-plan, re-teach, and re-feedback and this cycle is repeated till the pre-service teacher attains mastery in the use of the particular skill. It focuses on how instructions should be led by the teachers. In contrast TSPCK focuses on the classroom environment and the students' and teachers' perception about the topic. In addition, it focuses on teachers' Content Knowledge (CK) and pedagogical knowledge. It is based on the five knowledge components highlighted by Geddis (1993): i) Learners' prior knowledge; ii) Curricular saliency; iii) Big ideas; iv) Representations including analogies and metaphor; and v) Conceptual teaching strategies.

For the assessment of the practice lesson plans and its presentation, a single point rubric viz; Presentation Rubric was used (Appendix -3). Significance of the single point rubric was described by Fluckiger (2010) as it is a tool for each student to indicate: i) I know where I am going; ii) I know where I am now; iii) I know how to get there; and iv) I know how to get beyond.

LITERATURE REVIEW

Topic Specific Pedagogical Content Knowledge (TSPCK)

TSPCK, a model introduced by Mavhunga & Rollnick (2013), focuses on transforming the content knowledge of a topic into a form suitable for teaching. It is the basis by which knowledge of the subject matter of a particular topic is conveyed to pupils by packaging them for teaching, and that this capacity may be developed by focusing on selective knowledge components that are oriented to CK. This model helps a teacher to have deep knowledge about their students' understanding about the content and misconceptions. According to Deshmukh (2012), misconceptions are defined as 'incorrect interpretations or misunderstandings of an idea, concept, or process,' and are often a large part of a student' prior knowledge and experience. These misconceptions can be rectified by a teacher using historical development of concepts/theory, providing correct notions and their fine elaboration, by inter-relating concepts and sub-concepts, and by improving their knowledge (epistemological) about organization of topics/concepts/sub-concepts.

Microteaching

Microteaching gives a practice to teach in real classroom situations. It is a teaching technique used in teachers' pre-service education to train them systematically by allowing them to experiment with main teacher behaviors. According to Uzun (2012), this technique helps teacher candidates to experiment and learn each of the teaching skills by breaking the skills into smaller parts. During micro-teaching, a pre-service teacher conducts a class for a small group, for a short period of time and for a single concept of the content using a particular skill of micro-teaching which is then provided with feedback from peers and educators for the teacher's behavior modification. Feedback provides pre-service teachers information about their strengths and weaknesses. According to Thomas (2017), re-feedback is the most important component of micro-teaching for behavior modification of the teacher trainee in the desired direction. Msimanga (2020) stated that when student-teachers present micro lessons in groups, they are able to learn from a diverse group of people, their confidence is boosted, and cooperation skills are improved. After practicing each micro-teaching skill and its acquisition they are integrated for effective teaching in real classroom settings.

Single point Rubric

One of the strategies of improving the performance of a student-teacher is by giving them detailed feedback of their achieved performance and about the expected performance to meet the criteria of learning objective. Using a single point rubric, a teacher can provide detailed individualized feedback (Hashem, 2017; The Learning Accelerator, 2021; Nolan, 2018) to the students for meeting the mastery which helps the student to apply it in real life situations. It helps the student-teacher in building their creativity and meaningful learning. It gives a qualitative description of the level of achievement. The single point rubric was first published in 2010 by Fluckiger. According to her, one of the purposes of the single point rubric is "to provide specific written feedback on various aspects of students' work that will help them know how to improve." In this study, a single point rubric is used as suggested by Estell et al., (2016) that there is considerable potential in adopting single point rubrics for formative assessment in higher education. To the best of the knowledge of the researchers there is no study which reveals the TSPCK model incorporating integrated micro-teaching skills assessing the performance of pre-service teachers using a single point rubric. Hence this study is conducted for analyzing the TSPCK components as a supplementary framework while implementing a practice lesson plan combined with integrated micro-teaching skills using a single point Rubric for assessment of lesson plan and its observation.

RESEARCH QUESTIONS

The current study synthesizes the descriptive research regarding the application of TSPCK in integrated micro-teaching skills. Following research questions are addressed based on the responses collected from pre-service teachers:

RQ. 1 What are the perceptions of pre-service teachers in using TSPCK (components) during the presentation of their practice lesson for conducting integrated micro-teaching skills?

RQ. 2 What is the impact of implementing the TSPCK framework in designing practice lesson plans and during its presentation supplementing micro-teaching skills in pre-service education?

METHODOLOGY

Method

This study is based on a qualitative descriptive approach (Merriam, 2009). The study was conducted to study the impact of implementing the TSPCK framework in designing practice lesson plans and during its presentation, supplementing micro-teaching skills in pre-service education.

Sample

Purposeful sampling is widely used in qualitative research for the identification and selection of information-rich cases related to the phenomenon of interest (Palinkas, et al., 2015). The population of this study contains all the pre-service teachers admitted for the two-year degree course 2020-2021 at college of education and 81 students from Bachelor of education as sample is taken who attended 1-month online TSPCK coursework and submitted their lesson plans.

Data collection

Data was collected using i) Semi-structured interview, ii) Practice Lesson Plan, and iii) Rubrics. It is based on the study conducted by Tiraş (2019) which explored experiences of Science teachers' TSPCK in teaching ecosystems using semi-structured interview questions and classroom observations. On the same basis, this study implemented a rubric to collect data about self-assessment of the pre-service teachers during presentations and the feedback given by the researchers and faculty members (Appendix -3).

Data collection tools and related aspects for the study are shown in Table 3.3

Data Collection Tools	Related Aspect	Time
TSPCK Lesson Plans (as shown in Appendix-1)	(i) Learner's Prior Knowledge (ii) Curricular saliency (iii) What is difficult to understand? (iv)Representations including Analogies and Metaphors (v) Conceptual teaching strategies	After orientation of TSPCK model
Presentation Rubric	(i) Learner's Prior Knowledge (ii) Curricular saliency (iii) What is difficult to understand? (iv) Representations including Analogies and Metaphors (v) Conceptual teaching strategies	During the study
TSPCK Interview questions	Perceptions of pre-service teachers in using TSPCK lesson plans during micro-teaching skill	After the two presentations.

Table 3.3: Data Collection Tools and Related Aspects

In the next section, data collection tools are demonstrated.

DATA COLLECTION TOOLS

Interviews

In this study, the researchers used semi structured interviews to understand pre-service teachers' reflection on using the different components of TPACK model in the lesson plan and its presentation. Several open-ended questions were asked to the pre-service teachers in order to examine their understanding of TSPCK. First the interviews were transcribed and summaries were constructed for each pre-service teacher. Both authors subsequently coded categories and subcategories. Tallies were kept of how many times a student-teacher mentioned the category in the interview. Next, patterns were drawn for the 36 participants and tabulated for comparison based on the analysis based on the study by O'Brien (2017) in which Topic-Specific Pedagogical Content Knowledge (TSPCK) in Redox and Electrochemistry of Experienced Teachers was examined.

In-class Observation Notes

The Researchers observed the online presentation of 36 pre-service teachers. It was a follow up of the lesson plan which the pre-service teachers had submitted. The presentations were conducted in order to see how the pre-service teacher translated their plans and knowledge during their presentation. In accordance with the study done by Mohammed & Andrew (2021) for Assessing Teachers PCK Components using Parks' Pentagon Model, in which the researchers used classroom observation to capture the teacher's manifestation of PCK in action, for the current study too, the researchers gathered the data using single point rubrics from the feedback and re-feedback of faculty members and by researchers themselves and also from the pre-service teachers' self-assessment.

Construction of Rubrics

Construction of Rubrics was done by the researchers which contained the 5 components of TSPCK on which the pre-service teachers were assessed for their Practice Lesson Plans and its presentation. (Appendix -3)

INTERVENTION PROGRAMME

A course on (TSPCK) was designed for 81 pre-service teachers for a month in a pre-service education course (Appendix-2). 20 online sessions were conducted by the first author. The main objective behind the sessions was to let pre-service teachers and the faculty knows where, when and how the TSPCK should be used while implementing integrated micro-teaching skills as all the pre-service teachers and faculty members were new to the TSPCK Framework.

Intervention for understanding the Rubric and the content

The first session was an introductory session in which the objectives for conducting the intervention were discussed. The researchers gave an understanding about the expected work that was to be done by the pre-service teachers. Also, a detailed idea about the application of single point rubrics was shared with the pre-service teachers as this was going to be used for the self-assessment of their presentation (Appendix -3). A special session was conducted for guiding the faculty about the Single Point Rubrics and a discussion was conducted on the type and criteria of feedback that was to be given based on five components for lesson plans and its presentation. Following this session, 2 sessions were conducted for providing guidance about Knowledge (K), Content Knowledge (CK), Pedagogical Content Knowledge (PCK), and the knowledge base of teachers.

Intervention for understanding the content

In the next 5 sessions, the researchers explained about the five content-specific components of TSPCK, one per session. At the end of these sessions, the pre-service teachers were asked to share examples on any topic of their choice in order to make the sessions interactive and for clearing the doubts of the pre-service teachers and the faculty. On the completion of each session, a task was shared with the pre-service teachers on their computer drive. It was expected to be completed by the next session. The researchers examined the task of all the pre-service teachers and shared the feedback on which discussion was carried out at the end of next session.

Intervention for Designing and Submission of Lesson Plans

During the 10th and 11th session, the researchers explained the lesson plan having all the components of TSPCK. The Faculty assisted the researchers by helping out according to their respective methods. A draft of the lesson plan was shared with the pre-service teachers (as shown in Appendix-1). The pre-service teachers were requested to write the lesson plan and upload it on the drive. 81 pre-service teachers submitted their online lesson plans on a shared drive. The researchers and the faculty examined these lesson plans and gave feedback, which was followed by resubmission and re-feedback. This process was continued till the researchers were satisfied with the submitted work.

Intervention for Designing and Submission of Lesson Plans

After getting the satisfactory lesson plans, online sessions were conducted for the presentation of practice lesson plans. According to the method of teaching, pre-service teachers were allotted to their respective faculty depending upon their method of teaching viz. Mathematics, Science, Language and Social Studies. In this study, the first author was also in the role of faculty for Science method for this intervention program and assessed lesson plans and presentations of those having Science method. For the observation, 4 breakout rooms were created for each method. Each faculty member was allotted a breakout room with the pre-service teachers having their respective method. Each pre-service teacher was allotted 40 minutes for presenting their lesson plan consisting of 30 minutes for presentation and 10 minutes for feedback. During the session, the pre-service teachers were expected to take feedback and ask their doubts. Each faculty and the researchers themselves individually observed and interacted with each pre-service teacher, and provided them with a formative oral feedback on their practice presentation and online feedback on the Presentation Rubric sheet was given so that the pre-service teachers could improve on their skills prior to the final presentation. In all, 8 sessions of two and half hours each were conducted for trial and final observation. From the 81pre-service teachers, 36 presented their lesson plan. And from among the 36 pre-service teachers, 10 were selected for a semi-structured interview. Their consent was taken and two online sessions were conducted for it.

DATA ANALYSIS

To analyze the data collected from the submitted practice lesson plans, semi-structured interview and demo observation thematic analysis was done. Question wise documents were prepared and a query was run to explore the word frequency. Open coding from the acquired data was done at an initial stage and themes and sub-themes were formed. The analysis is based on Bhamani's (2020) suggestions which affirm that the codes, themes and sub-themes verified by the researchers confirm coherence in interpretation.

Content analysis was used for the analysis of the data and visual arts made by students. Content analysis can be applied to a whole variety of data (including nonverbal data, such as pictures, drawings, gestures, etc.) and in relation to a variety of research questions (Figgou & Pavlopoulos, 2015).

RESULT AND DISCUSSION

In this study all the five components which the Mavhunga & Rollnick (2013) model provided, were taken into consideration. In the following part, the analyses of each of the five components are represented in detail.

Learner's Prior Knowledge -

It is the previous knowledge a teacher should have before hand while teaching a topic about 'what does the student know about the topic being taught?' Students have their own conceptions about their prior knowledge. Sometimes it is inaccurate, which should be restructured before adding new knowledge.

During the study it was observed that most of the student teachers had written prior knowledge in their lesson plan according to their assumptions, and during their presentation some of the student-teachers noticed that the students were lacking the assumed prior knowledge. But without giving understanding about the gap in the students' knowledge, the student-teacher continued their teaching. Some pre-service teachers, even after writing learners' prior knowledge in their lesson plans, assumed the same and proceed to teach without checking it in the class. Some pre-service teachers were unaware of 'what students already know' so they hadn't written it in their lesson plan and hence, this was not observed during the execution.

The faculty observed that pre-service teachers have written about students' misconceptions in their lesson plans based on their assumptions because they were not having the experience of teaching. When they came across a few misconceptions, some of the pre-service teachers made students unlearn and relearn their misconceptions and after filling the gap in their knowledge, they continued their further teaching.

Curricular saliency

Teachers should know the importance of the topic in the curriculum, what is easy or difficult to teach and the prior knowledge required to build the new concept. Which topic is included or excluded and what are big ideas of the topic.

It was observed that some of the pre-service teachers had written about all the sub-points of curricular saliency in their lesson plans. However, those who had not written it updated and resubmitted it after getting feedback from the researchers and faculty.

All pre-service teachers mentioned big ideas in their lesson plans but were unable to present the. Most of them did not have any idea about the reason behind including the topic in the curriculum. Moreover, most of the pre-service teachers did not have the idea about which prior knowledge is required to build the new concept. Also, most of the pre-service teachers finished their lesson before time - very few finished it on time as they did not have any teaching experience.

What is difficult to understand?

It is essential for a teacher to know which topic is difficult to understand for their students. The study found that all the pre-service teachers had written about it in their lesson plan depending on their assumptions or experiences. During the presentation, it was observed that the topic which is difficult for the individual student-teacher to teach, he/she assumes that their students will face difficulty in understanding it. In addition, the faculty found that some students were unable to present the lesson plan, maybe due to the lack of proper CK or maybe they did not have the teaching experience.

Representations including Analogies and Metaphor

For deeper understanding teachers should use representations including analogies and metaphors from various sources in the form of audio, video, animations, simulation, photographic images, and drawings and diagrams from textbooks. It was observed that pre-service teachers had drawn the figures of various learning resources in their lesson plans, and some of them used it during their presentation very efficiently. But during the interview, it was found that they were unable to answer the reason for selection of that particular learning resource. Hence, pre-service teachers should be provided training for understanding the importance of representation, analogies and metaphor, their types, selection, handling and reason behind choosing the particular representation.

Conceptual teaching strategies

Teachers should know the appropriate strategy for the transformation of content knowledge. It can be ABL, PBL, Question answer approach, Problem solving, flipped classroom, constructivist as think-pair- share, Jigsaw, whole class teaching, group work etc. which can be used for the development of conceptual knowledge. The teacher should have the understanding about the most suitable teaching strategy to make the topic easily understood to the learner. It was observed that most of the pre-service teachers used a question and answer strategy in their lesson plans and their presentation, while remaining used the whole class teaching strategy.

Findings of the interview:

The assessment and interview data provided evidence of impact of TSPCK

1. None of the pre-service teachers in this study were aware of the TSPCK model. They showed their interest in using them in their future classroom.
2. The various tasks gave clarity in understanding of the TSPCK framework
3. They were interested in taking the training about TSPCK components in future again.
4. They were lack in understanding students' misconceptions, previous knowledge, and curricular saliency, what is difficult to understand and in selection of appropriate learning material and its handling as they were not having teaching experience.
5. Components of TSPCK depend largely upon teaching experiences.
6. They mentioned in the lesson about the components plan but forgot to implement it.
7. TSPCK training should be provided during the first semester of teacher education so that it will help them to incorporate all the components in all the six semesters which will give them hands-on practice.
8. TSPCK as a supplement in micro-teaching improves confidence, as they will have prior knowledge about the students' understanding related to the content and PCK of the content being taught.

CONCLUSION AND RECOMMENDATIONS

The study included an intervention in which the TSPCK framework was used in designing practice lesson plans and its presentation supplementing micro-teaching skills in pre-service education. The findings of the research revealed that pre-service teachers and faculty both were unaware of the TSPCK framework. Pre-service teachers knew the importance of planning lessons; however, they found some difficulties during implementing TSPCK in their planning. They lacked actual prior knowledge, misconceptions, what is difficult and easy to understand for a student, probably because they didn't have experience of teaching in actual classrooms. Teachers should be given training about conceptual understanding and misconceptions that students might have about the topic. A study conducted by Deshmukh (2012) states that for determining conceptual understanding and misconceptions, teachers should use open-ended questions, two-tier diagnostic test, concept mapping, prediction-observation explanation, interviews about instances and events, interviews about concepts, drawings, and word association etc. Participants of the study found TSPCK as a supplement for micro-teaching. It would help to improve their confidence, as they would have prior knowledge about the students' understanding related to the content and PCK of the content being taught before actual teaching. This method offers real-time teaching experiences and opportunities to learn about new teaching techniques, teaching skills, awareness of personal skills, and competencies and students' understanding and PCK.

The results suggest that opportunities should be created for pre-service teachers to get acquainted with TSPCK during their lesson planning and practice. In addition, Pre-service teachers should be provided with the understanding about types, importance and the mechanism of using representations as- How, When, Which, Where and what while using them.

Benefit for Community

This study will develop effective teaching skills among pre-service teachers which will help them to deliver effective instructions and it will ultimately assist them for their professional growth.

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Appendix- 1

TSPCK Lesson Plan

<table>
<tr><td colspan="7">Name - Date -
Supervisor - Method -</td></tr>
<tr><td colspan="7">What makes the topic easy or difficult to understand for students? -</td></tr>
<tr><td colspan="7">Students already know -</td></tr>
<tr><td colspan="7">Students doesn't know -</td></tr>
<tr><td colspan="7">What teachers know -</td></tr>
<tr><td colspan="7">What teacher want students to know -</td></tr>
<tr><td colspan="7">Topics to be avoided-</td></tr>
<tr><td colspan="7">Big Concept -</td></tr>
<tr><td colspan="7">Importance of the topic / connection with other concepts-</td></tr>
<tr><td rowspan="2">Subtopic / Sequencing of order of teaching</td><td rowspan="2">Previous knowledge</td><td colspan="2">Big ideas</td><td rowspan="2">Misconceptions</td><td rowspan="2">Representation you choose and why</td><td rowspan="2">Teaching Strategy</td></tr>
<tr><td>Easy</td><td>Difficult</td></tr>
<tr><td></td><td></td><td colspan="2"></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td colspan="2"></td><td></td><td></td><td></td></tr>
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</table>

Appendix-2

Session no.	**Purpose**
1st	-Introductory session - Objectives for conducting the intervention -Understanding about the expected work -Application of single point rubrics and sharing it.
2nd	-Guidance for faculty- Discussion on giving feedback using the Single Point Rubrics in lesson plan and its presentation
3rd & 4th	-Guidance about Knowledge(K), Content Knowledge (CK), Pedagogical Content Knowledge (PCK), and the knowledge base of teachers.

5th to 9th	-Guidance on five content-specific components of TSPCK
10th & 11th	-Guidance on lesson plans having all the components of TSPCK
12th to 15th	-Observation of practice presentation
16th to 19th	-Observation of final presentation
20th & 21st	-Online Semi-structured Interview

Presentation				
Sr. no.	**Observer**	**Method**	**No. of students**	**No. of online sessions (for 2 rounds)**
1	Researcher	Language	6	4
2	Faculty	Mathematics	9	6
3	Researcher	Science	11	8
4	Faculty	Social Studies (His -3, Geo- 4, Commerce -2, Eco- 1)	10	8

Appendix -3

Single-Point Rubric			
How I will revise to better meet criteria **Glows Strong aspects of**	**Performance criteria** **Curricular Saliency — I think it is right …**	**How I know met the Criteria Grows How u can strengthen your work**	**How I went beyond the criteria**

your work			
	Subtopic / Sequencing of order of teaching		
	Students already know- (pre-service teachers ask questions based on students' prior knowledge)		
	Students doesn't know - (On the basis of students answer get to pre-service teacher know)		
	What teachers want students to know - (How the instruction is led by the pre-service teacher to give the understanding of the topic?)		
	Big ideas - (Have the Big concept introduced to the student?)		
	Easy - (Topics which are easy to understand for student) **Difficult-** (Topics which are easy to understand for student) Pre-service teacher presenting the content taking into consideration the difficulty level of understanding of the students.		
	Misconceptions- (Have the pre-service teacher corrected the misconception if there in the topic)		
	Representation Was the representation appropriate for the topic?		
	Teaching Strategy Was the Teaching Strategy appropriate for the topic?		
	Importance of the topic / connection with other concepts/subjects Has the importance of the topic shared with the student or its relation with other subjects?		

EXPERIENCING COVID-19 PANDEMIC FROM THE LENS OF REALISTIC MATHEMATICS EDUCATION (RME)

Kumar Gandharv Mishra

Independent Researcher, India

mishrakumargandharv@gmail.com

The paper tries to put the experiences of the author during the pandemic Covid-19 in the context of Realistic Mathematics Education (RME). RME emphasises on 'realistic' situations in the learning process of mathematics. When Covid-19 was declared as a pandemic by the WHO in March 2020, and lockdowns took place across different parts of the globe including India, several rules and restrictions were brought in to control the pandemic. These new rules and restriction were meant to control human behaviour and movement. Infact, these changes generated unfamiliar situations for humans to act, adapt and survive. The paper describes these 'unfamiliar situations' as 'realistic' situations defined in RME. These situations offer mathematisation. The paper describes the experiences of some of the situations originated as a result of the pandemic, in the context of RME.

Keywords: Realistic Mathematics Education, RME, Mathematisation, Covid-19, Pandemic

INTRODUCTION

What is Realistic Mathematics Education?

Realistic Mathematics Education (hereafter RME) is an approach which focuses on learning mathematics through 'realistic' situations. These situations serve as a source for initiating the development of mathematical concepts, tools, and procedures and as a context in which students can in a later stage apply their mathematical knowledge, which then gradually has become more formal and general and less context specific (Heuvel-Panhuizen & Drijvers, 2014). It is a misunderstanding that RME means task should start with a real life story. Infact it should be experiential (Drijvers, 2018; Drijvers, 2020). In RME, 'realistic' situations don't necessarily mean a real situation or a concrete structure to do mathematics, but it has a broader meaning. Here, students are offered problem situations which they can imagine. In RME, problems presented to students can come from real world but also from the fantasy world of fairy tales, or the formal world of mathematics, as long as the problems are experientially real in the student's mind (Heuvel-Panhuizen & Drijvers, 2014). The development of RME approach started in the 1960s in the Netherlands with initiation of a project on mathematics in primary school, by mathematicians Edu Wijdeveld, Fred Goffree and Adri Treffers. Later on, Hans Freudenthal (1905-1990) contributed to the development of RME theory, who considered mathematics as a human activity. RME is based on six principles for teaching mathematics which were developed and reformulated by Treffers over the years. These principles are: Activity principle, Reality principle, Level principle, Interwinement principle, Interactivity principle, and Guidance principle.

Covid-19 pandemic and disruption in human behaviour

With the identification of novel coronavirus (Sars-Cov-2) in December 2019 (World Health Organization (WHO), 2020) and spread of coronavirus around the globe by March-April 2020, various movements came to a halt. Different parts of the globe went under lockdown. In India, a strict lockdown was first announced on March 24, 2020 (Press Information Bureau (PIB), 2020). As soon as the lockdown was announced, people rushed to market to collect whatever they could. Soon, protocols were released about the activities and appropriate behaviour to be followed during lockdown. It brought a sudden change in human behaviour for which everyone was unprepared, but people tried to adjust and adapt accordingly. It was suggested that people should maintain physical distance (social distancing) of atleast 1 meter from each other (MoHFW, 2020; WHO, 2020). Pictures and videos of people standing in queue by mainating physical distance in front of ration shops drew a lot of media attention. Unfamiliar situations emerged, as at various places it was tough to maintain the required distance due to space constraints. Apart from this, 'contact tracing' was used as a preventive measure to trace persons who came in contact with a Covid-19 case or with those who returned from other country or other state (during the first 3-4 months of rise of Covid-19 in India). The 'number' of daily cases in a locality was also a point of discussion in public. People used to discuss the rising number of cases in different countries and different states. At some higher level, some also discussed it through graphs. The development of a vaccine and drug for the coronavirus and remembering the number of days left in quarantinne for someone were some frequenct points of discussion. In short words, the points of discussion regarding combating the pandemic come down to mathematics (it will be explained in the next section). People did discuss Covid-19 related mathematics in an implicit way.

Everyone would have experienced these situations. Like everyone, the author also experienced some of these 'situations' created during the pandemic. Learning about the spread of pandemic and adapting to new behaviour was also a challenge. It also led the author to write couple of articles on the mathematics related to Covid-19 situations. Infact, that writing activity was nothing but an expression of author's mathematisation experiences of Covid-19 situations. The paper briefly discusses the mathematics of some 'situations' and tries to present the 'mathematisation' experiences from these situations in the context of RME.

PANDEMIC SITUATIONS AND RME

Covid-19 pandemic generated new 'situations' for people to act and adapt. Some of the 'situations' are discussed here in the context of RME.

Queue and seating arrangement with social distancing

The concept of social distancing provided an opportunity for people to be conscious of 'measurement'. People stood in queue in front of ration shops or ATMs by marking some distance between each other. It was recommended that people should maintain a distance of at least 1 meter from each other while meeting or talking. Planning such seating arrangement was no less than a puzzle. The author also experienced various situations related to seating arrangement and tried to discuss mathematics of such situations through an article (Mishra, 2020a). One of such situations has been presented here:

> "Suppose, you go to an ATM to get some cash. You find two ATMs - Bank A and Bank B. The ATMs are fixed close to each other. You could realise that the distance between these two ATMs is less than 1 meter. Good news is that people, who are queued up in front of each ATM, stand at a distance of 1 m from each other with the help of markings made on floor. As the two ATMs stand close, you find that persons in one queue do not maintain 1m distance from persons in the next queue. What would you do in such situation? Can you come up with a new plan to stand in queue?" (Mishra, 2020a)

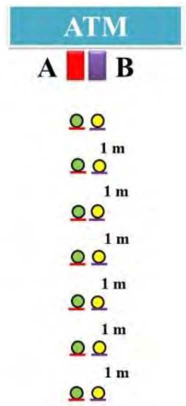

Figure 1: A 'realistic' situation- Using an ATM during pandemic. (Reproduced by permission from Science Reporter)

The pandemic 'situation' (Figure 1) provides an opportunity for students and people in general to mathematise, experience it, imagine it and come out with a new queue arrangement. In the new arrangement (solution) people can stand on alternate markings in each queue. In such case, the distance between a person in queue A and other person in queue B will be greater than 1m. One can estimate the distance (Figure 2) between A and B, as it will be the hypotenuse of a right angled triangle with one of the sides as 1 m. The hypotenuse will be greater than 1m in any case, whatever the measure of remaining side be.

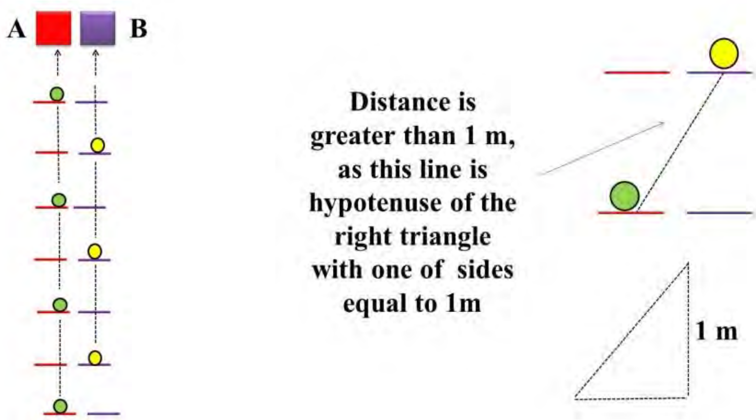

Figure 2: Solution for the ATM situation. (Reproduced by permission from Science Reporter)

Contact tracing and networks

'Contact Tracing' was one of the effective measures to combat the spread of coronavirus by tracing suspected cases i.e. to trace those persons who have come in contact with a Covid-19 positive person and test them-isolate them. In a way, contact tracing is a part of solving networks created with contact (travel) history of confirmed positive cases (Mishra, 2020b). It was a 'realistic' situation to introduce, teach and popularise Graph Theory among students. As the concept of contact tracing gained popularity, people had also become self-conscious of their contact networks. It might have happened with you also where you would be recalling you contact network, the number of the friends you met on a particular day and the people who had met those friends whom you met on that day. You must have also visualised such network. This network (Figure 3) was a mathematisation of a meeting activity in a pandemic situation.

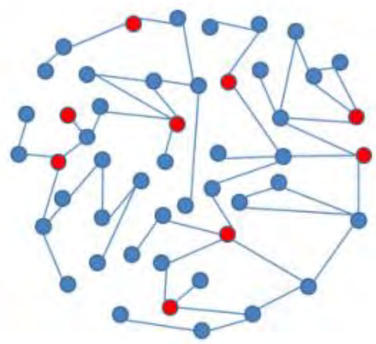

Figure 3: An example of a network: Dots represent nodes. Edges represent a contact between two persons. The red dots represent an infected person (population).(Reproduced by permission from Science Reporter)

Pandemic Graphs

Perhaps, it could be the first time when graphs became a point of discussion out of the classroom or research institutes. Covid-19 graphs were being published and discussed in public and in news. Logarithm graphs were the most popular ones. Such was the rise in number of daily Covid-19 cases that logarithm scales proved more useful than linear scale (which is usually taught in school curriculum). Unlike examples and data provided in books, this was probably the first time people and students could experience such large numbers (number of Covid-19 cases) in data. While the interval on one of the axes remains fixed in linear scale graph, the interval generally increases 10 times (not necessary) in a logarithmic scale graph. When the number of cases increases in thousands or millions, logarithmic scale is used (Mishra, 2020b). Never ever before this, the author had encountered logarithm scale graph based on daily life events (not to confuse with mere introduction of a logarithm function graph while studying functions) in school. The pandemic generated a 'realistic' situation to use logarithm scale and understand it. These graphs also provided students the context to understand the relevance of calculus; the nature of function- whether it is increasing or decreasing and the relevance of maxima and minima. For example, Jungic (2020) shares the experience of teaching differential calculus during Covid-19.

Sequential thinking and sanitizer

When was the last time 'sanitizers' made news headlines? Infact, it was a foot operated sanitizer which drew a lot of attention ("Now a foot-operated sanitiser dispenser", 2020; "Railway...stations", 2020). Why was it so important? What was wrong with the normal hand sanitizer? People wanted to avoid 'touching' any surface with hands. The normal hand sanitizers and tap water did sanitize hands but the purpose failed as the hand sanitizer and tap (which surface can come in contact with hand of multiple people) needed to be pressed/opened and closed with hands again. The 'situation' provided a scope to think sequentially, break the process into number of events (in order of events – opening the tap with hands, washing of hands and then closing the tap) and come out with a different event to break this chain. A child also developed a foot sanitizer and gifted it to the Lieutenant Governor of Puducherry, India (Nandigosha TV, 2020).

Stockpiling during lockdown

One must have observed and experienced a rush to buy products from market as well as stockpiling of products a day before lockdown or as soon as lockdown was announced. The situation can be used as a 'realistic' example for Game theory. Here, individuals try to fetch some products before the lockdown starts and so does everyone which ultimately creates chaos at the same time. It leads to unfavourable situations: (i) breach of social distancing (ii) Stockpiling (iii) Rise in prices of products. This Game can be seen in these following contexts: (i) When customers act as players, (ii) When shopkeepers and customers act as the two players. In such situation, if a person A doesn't go out but others go for shopping, products would run out of stock and consequently person A will lose. This is what everyone thinks and goes to shops; consequently crowd gathering takes places, social distancing breaks, stockpiling and prices of products rise (A customer-customer game) (Mishra, 2020b). The situation is similar to the famous Prisoner's Dilemma. This experience was an experiential activity. Such experience can count for learning-teaching mathematics (Game Theory) through social activity (though not done intentionally).

Mask behaviour and risk perception

Poletti, Ajelli & Merler (2012) applied game theory to study the behaviour model. According to their study "Risk perception and effectiveness of uncoordinated behavioral responses in an emerging epidemic" (2012), the biggest changes in behaviour happens when there is an equal division of reactive and unreactive people; people who change behaviour are less likely to be infected and at a certain point in the epidemic those people have an advantage in the population, and others begin to copy their behaviour. During these times, one would have often 'experienced' such behaviour- where individuals don't wear masks quoting reasons that their peers or a significant population doesn't wear mask. If majority of the people wear a mask, everybody else starts wearing a mask. The study also suggests that people are more responsive when the symptoms of the disease are more evident, like coughing and sneezing. Indian Council of Medical Research (ICMR) had communicated that 80% of persons infected from Sars-Cov-2 were asymptomatic or mild (Ghosh, 2020). As the number of asymptomatic cases increases, people also become less responsive towards protocols and preventive measures. One would have often experienced such types of behaviour in their society. In other words, the pandemic generated a 'situation' to experience what was discussed mathematically in a research paper (Winner of the Bellman Prize 2015 for the best paper in 2012 in *Mathematical Biosciences*) (Poletti, Ajelli, & Merler, 2015).

DISCUSSION AND CONCLUSION

The table below lists major mathematical concepts (mathematisation) associated with some pandemic situations and the respective popular terminology. The mathematics associated with these pandemic situations may also extend beyond this list.

Covid-19 pandemic situation	Related terminology (popular during Covid-19 pandemic)	Embedded mathematical concepts
Queue, Seating arrangement	Physical distancing	Distance, Measurement, Position

Travel history, Contact with an infected case	Contact tracing	Networks, Graph theory
Number of Covid cases	Covid data, Figures	Different types of graphs, importance of axes, Functions
Hand Sanitisation	Touch free/Hands free santisation	Sequential thinking
Purchase of necessary items, Rise in prices of essential commodities	Stockpiling/Hoarding	Game theory
Wearing masks, gloves, face covers etc.	Hygiene, Covid Attire, Covid appropriate behaviour	Risk perception due to division of population

Table 1: Summary of mathematical concepts associated with some of the pandemic situations

While writing the articles and experiencing the pandemic in 2020, the author didn't perceive these situations from the lens of RME, but with time as these situations became a part of daily life, the author could relate it to RME. Now, it has been more than two years since the spread of pandemic Covid-19, people have learnt about the pattern and behavioural changes to be followed during lockdown as well as during the rise of Covid-19 cases. Even students have learnt about the protocols to be followed during various 'situations' of the pandemic, they can experience it in their daily life, imagine it and treat it as 'realistic'. RME also talks about experiencing the activity (real or imaginable) and students have experienced the pandemic Covid-19 every hour and every day of their life. The stories of pandemic and the 'situations' originated due to the pandemic can provide a real as well as imaginable opportunity for students to mathematize. Covid-19 situations can be studied under teaching principles of RME. For example: the physical distancing (Figure 1) activity majorly reflects 'activity', 'reality' and 'interactivity' principle. However, it shouldn't be inferred that students should be intentionally exposed to pandemic situations to mathematize. The pandemic situations are imaginable and have been experienced by students in the past. The activities and tasks related to these 'situations' can be developed according to the teaching principles of RME. The pandemic situations can be used for contextual learning and, propagating mathematics and teaching mathematics in the context of RME. Infact, it is also a 'realistic' situation for the public in general to mathematise.

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HIGH SCHOOL STUDENT'S PARTICIPATION IN SCIENTIFIC INVESTIGATIONS: ITS IMPACT ON THEIR COMPETENCIES AND ATTITUDE TOWARDS SCIENCE

Venkata Krishna Bayineni

Department of Biology, Prayoga Institute of Education Research, Bengaluru, Karnataka, India

he/him/his

krishna.bayineni@prayoga.org.in

Open-ended investigations for high school students provide authentic contexts for learning science in which students engage in research with practicing scientists. The purpose of this study is to see how high school students respond to a scientific research environment. The opportunity to participate in scientific research projects was offered to high school students in working laboratory groups at a research institute. We looked at how students worked on projects with expert scientists and its impact on their learning attributes, competencies and attitude towards science. As part of this programme, students participated in both laboratory practises and seminars and they were evaluated on their progress in conceptual understanding, competencies, and views about the nature of science. Student interviews and student survey forms were the primary data sources. Students' competencies, conceptual knowledge and abilities have improved, and there is an improvement in students' attitudes to science. We looked at students learning in-depth through their poster presentations, which revealed that they had developed more sophisticated ways of thinking about the research problems. The findings revealed that effectively engaging high school students in the conduct of real science research can improve their competencies and attitudes toward science.

INTRODUCTION

Practical independent research projects (PIRPs) can take a wide variety of forms, but they all share several common characteristics. They are, in essence, student-led, open-ended research inquiries that are frequently aided by a teacher and/or a practicing scientist in a research laboratory (Bennett et al., 2018). Students have significant influence over the question(s) that they expect the practical work will answer, as well as the manner in which the work is undertaken. IRPs are typically done by high school students but not solely, and the results of the investigation is open at the upper high school level, in that neither the teacher/researcher nor the student knows exactly the outcomes of the investigation. IRPs may also include external sponsorship and be linked to science competitions, fairs, and reward programmes.

PIRPs can also include a variety of evaluation methods, such as report writing and student presentations. They frequently occur outside of the regular school science curriculum. In other countries, efforts to engage students in more authentic scientific procedures have proven more successful. Research laboratory experiences for high school students in Israel, for example, successfully mimic scientific inquiry, particularly in terms of generating research questions (Lederman & Abd-El-Khalick, 1998). Students in Australia have been able to participate in independent and extended experimental investigations as a result of attempts to embed chemistry instruction in meaningful situations (King et al., 2007). Educators in Germany have tried organized pre-experimental activities that have resulted in pupils developing research questions and plans (Neber & Anton, 2008). The national curriculum in the United Kingdom has made scientific research in school science a priority. According to the researchers, these investigations have the potential to improve both procedural and conceptual understandings of science, particularly when it comes to the importance of evidence (Duggan & Gott, 1995).

Involvement in scientific inquiry can range from simple classroom activities to lengthy research efforts in laboratories. The more authentic the research experience, such as a PIRPs led by a science professional, the more likely students will learn about scientific inquiry (Barab, 2001). So far, the programmes presented have aimed to make school science more like real science. Creating learning chances in the midst of science as it is being practised is a different technique with comparable goals. In this approach, students are paired with mentor scientists to perform scientific inquiries.

Experiential learning of science in the Indian scenario

The science education system should emphasize the practical understanding of the principles of science with reference to modern technological advances. What our India needs now is Scientific Humanism i.e., a concept that involves progress in technology in relation to our cultural, economic, social spiritual, ethical and human values. This should be the aim of our school and higher science education (Kalra, 2008).

The decision taken by the government to overhaul the entire system of education is a welcome step. The NEP 2020 was approved on July 29, it is set to reconfigure the 10+2 years schooling system in India with a new 5+3+3+4 years system. These phases are strictly curricular and pedagogical in nature and are intended to optimise learning. For conceptual understanding, NEP suggests a hands-on experiential learning approach, often enabling learners to explore topics for holistic understanding across disciplines. The introduction of experiential and interdisciplinary learning methods would ensure that students will have a more meaningful, holistic and coherent learning experience (Panditrao & Panditrao, 2020).

Purpose of the study

Project-based learning has a lot of potential as an instructional approach for developing real inquiry in science project work. Despite its widespread use in other nations, this strategy is relatively new in Indian schools, with little research to back it up. Thus, it is of interest to study how investigative science projects can be implemented in a class at the secondary school level, and how the students respond to this mode of learning.

MATERIALS AND METHODS

Participants and study context

This study was conducted in the context of the education research program that encourages school students to participate in research. The program is designed for high school students from Classes 9 to 12 with a deep interest in science, who are passionate about pursuing a career in science research. The class of 12 high school students (14–15-year-old) worked in five groups of two or three members each. Students were selected through the personal interview process. Of the group, 9 were male, 2 were female and they came from urban districts of varying socioeconomic status. Each group worked on a self-selected project topic related to one of the themes ‘Green chemistry and Technologies’, ‘Food and Agriculture’, ‘Ecology and environment’ and ‘Wellness’. Students in a project group are paired with a science research faculty member and allocated to a specific research project in the mentor's lab. The five research projects covered in this study included a variety of qualitative and quantitative methods ranging from descriptive to experimental. Students spend an average of 24 hours per week in their designated laboratories. Students also attend lectures and seminars on variety of science topics. At the end of the programme, students submit their research findings in a research article and a formal oral presentation. Student research projects varied from biological and environmental science to chemical science. Table 1 summarizes each of these participants and the nature of their specific research.

Data collection and assessment

The students were asked to respond to statements that may or may not describe students' beliefs about their learning. This instrument is used as a common assessment tool as a means of measuring participant gains in competencies. They are asked to rate each statement on a Likert-type scale by selecting a number between 1 and 5 (1 - 5): Strongly disagree, disagree, don't know, agree, strongly agree.

The students were asked to choose one of the above five choices that best expresses their feeling about the statement. Also, they have stated how these practical independent research projects impacted them. The statements of the instrument were designed to assess students' understandings of scientific inquiry, in conjunction with the follow-up interviews. They were designed to evaluate their understandings of aspects of doing research (curiosity, perseverance, experimentation skills, patience, integrity, self-driven, openness, planning, analysis, logical reasoning, problem-solving, data collection, research interest, communicating results) to understand their competencies and their passion towards science. These skills and competencies are very much essential and currently sought after in a researcher (Ulrich, 2013). Content and face validity of the instrument used was provided through modifications suggested by a panel of three science educators. The analysis focused on generating profiles of the participants' understandings of the nature of science and scientific inquiry before and after their research experiences. Also, we looked at student learning and their presentation skills in depth through their poster presentations.

RESULTS AND DISCUSSION

Analysis of the PIRPs responses revealed that participants' competencies and their understandings of assessed aspects of the nature of science for the most part were consistent. The details of student participants and the nature of their specific research are given in Table 1. Furthermore, analysis of the post-research programme interview data revealed that over the course of the 3-month duration, students' understandings about the nature of science has significantly changed. The students' understandings of the nature of science were similar to those reported in prior investigations in that they were mostly inadequate or otherwise inconsistent with modern views of the nature of science before they began their individual research projects (Randy L. Bell 2002). Throughout all stages of the inquiry, all of the participants acknowledged some role to creativity. By participating in research activities, they have improved their experimenting and analysing skills. The results of the post-research questionnaires and interviews revealed a considerable shift in participants' perceptions of science and their enthusiasm for it.

Sl. No.	Student details	Project Title	How have these practical independent research projects impacted you?
1.	Suvratha Herur Age: 16 Class: 10th	In vitro analysis of antibacterial activity of *Dombeya wallichii* plant extracts against food pathogens	*"Learning science concepts or topics as a subject and through research experience is very different from one other. As I have experienced both reading about an equipment and using it, I can confidentially say that learning science through using it is much more. Identifying a problem, formulating a plan and a solution is a major learning point in research which is also essential in learning other concepts."*
2.	Shreeadithya Kashyap Age: 14 Class: 9th		*"I take more precautions while during experiments. Earlier I was not caring about some little things. But now I know that those little things are important. I organise things more neatly in my life which has motivated me to take biology in my future career. The experience was informative, fun and motivating."*
3.	Sachin Vashisht Age: 16 Class: 10th	Effect of coating seeds with micronutrients and bacterial consortia on stomatal conductance and yield at different stages of plant growth	*"I have become more curious and more able in terms of handling experiments, problem-solving, coming up with an experiment to verify our hypothesis. Most importantly I have become a more patient and perseverant individual. I have loved taking up in these projects and now I am much more interested in science."*
4.	Dhruva Shankara Age: 15 Class: 10th		*"It has impacted me in a unique way. I have learned to use and master some instruments in the lab. It is a whole different world from school. This will surely be a memorable experience and a lesson for life to me. I am grateful that I got the opportunity to work for these projects."*
5.	Punya Shree Age: 16 Class: 10th		*"Doing research has improved my thinking skills. I have understood that we always don't need to get positive results. We should be able to handle both positive and negative results. My patience has increased to a large level. My skills of doing teamwork have also increased a lot. After doing research now I am able to listen and understand other people's views. Now I am able to work better with chemicals, equipment and I am able to understand the procedures better. I am also able to analyse the procedure and work according to it."*
6.	Chinmaya Praveen Age: 15 Class: 10th	FTIR analysis of kidney stones and antibacterial activities of cranberry extracts.	*"These projects have increased my scientific curiosity. They have improved my analytical and problem-solving skills. I have learnt how to handle some instruments which are very useful and how to behave in a laboratory. These research projects have taught me to always have an open mind. I have been inspired and want to continue doing research. It has increased my wonder for science. I think these skills that research has taught me will be useful not only while doing the project, but in my life as well. I learnt a lot and thoroughly enjoyed doing these projects."*
7.	Vishwajit Adiga Age: 15 Class: 9th		*"These research projects have made me think in many ways and also it has increased my patience."*

Sl. No.	Student details	Project Title	How have these practical independent research projects impacted you?
8.	Samanyu Chandra Age: 16 Class: 10th	Identifying the relationship between stomatal conductance, specific heat and thermal conductivity for leaf samples	*"If I do some mistakes, I try to rectify immediately instead of dwelling on the matter that I have made a mistake. It has also developed curiosity and passion towards science and research."*
9.	Varnika K Age: 15 Class: 10th		*"I am sure and confident that I can handle some equipment at the research lab. And I am sure this will help me a lot in the future."*
10.	Sameer Jois Age: 16 Class: 10th	Can copper displace zinc from its solution?	*"The research projects were very exciting. It has allowed me to think more logically. I have been looking at things from different angle. Now I am more passionate about science than ever. I would like to perform further more research projects."*
11.	Pranav Sharma Age: 15 Class: 10th		*"The project sessions made me more curious about science. It has made me think of more possibilities. It has helped me to learn the current science more easily because of the interest built-in science by research."*
12.	Saathvik Bhaaradwaj Age: 16 Class: 10th		*"These projects have made me more capable of doing things independently. My thinking skills have improved a lot. In research thinking only in one way doesn't help at all. You need to think about different aspects of the topic you are researching. I have improved on that a lot. I am also more confident in the work I do."*

Table 1: Student participants and the nature of their specific research

Students have directly ascribed these significant shifts in their understanding of science to their research projects. The introspective nature of the students undoubtedly aided the effect of this epistemic requirement (Ryder & Leach, 1999a). Although students gained proficiency in the many phases of scientific inquiry (science as a practise), few displayed a greater knowledge of the essence of scientific inquiry (learning about inquiry). The participants obtained an understanding of numerous facets of science, including how to organise investigations, establish hypotheses, gather and evaluate data, construct explanations, and present their findings, after participating in an intensive 3-month science research project. Indeed, many of the participants considered that their participation had taught them more about science. The students have acquired abilities and traits (integrity, self-driven, openness planning, logical reasoning) to do their scientific inquiry. The lab safety and other prescribed experimental procedures figured prominently among the participant's descriptions of their work and what they had learned. The student poster presentations revealed that they had developed more sophisticated ways of thinking about the research problems and learnt the concept in-depth (Fig. 1). The fact that many of the students' projects required substantial data collecting and conclusion formulation was evident in their descriptions of what they had learnt. In addition to data collecting, students were given duties for the lab's day-to-day operations and assisted in the resolution of any issues that arose.

Figure 1: Students during their research poster presentations at Prayoga

CONCLUSIONS

The high school student participants had a wealth of experience in science in terms of carrying out the scientist-designed research projects. Formulating broad ideas, narrowing and refocusing them into research questions, and designing investigations are all important aspects of the scientific process that are often overlooked in high school science. One benefit of PIRPs is that students may have the opportunity to participate in the early phases of the scientific process. It is, however, challenging for them to complete their projects within the limited time frame of the research programme. The study initiatives clearly provided many possibilities for participants to learn and experience science. Certainly, students have developed new skills specific to the projects on which they worked. Students' awareness of some of the abilities associated with learning science that are often addressed in high school curricula grew as a result of their participation in PIRPs.

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NUMERIC EQUATIONS: A KEY STEP IN SOLVING THE EQUATION PROBLEM

Craig Pournara[1,#] and Shikha Takker[1,*]

[1]University of the Witwatersrand, South Africa

[#]Craig.Pournara@wits.ac.za, [*]Shikha.Takker@wits.ac.za

Teachers know, and research confirms, that learners have difficulties in solving linear equations. Apart from difficulties with the formal procedures for solving linear equations, their difficulties also relate to conceptions of the equal sign and equality; difficulties in simplifying algebraic expressions and difficulties with arithmetic operations on integers and fractions. We propose the use of numeric equations to introduce learners to algebraic equations, emphasising the idea of balance and foregrounding structural views of working with numeric expressions, rather than merely calculating answers. We discuss a range of tasks involving numeric equations to illustrate our ideas.

INTRODUCTION

Solving linear algebraic equations may seem trivial to those who have mastered school algebra. But teachers of lower secondary school mathematics know well that many learners have difficulty in learning such apparently "basic" algebra. Through our work with teachers, analysis of learner errors and our materials development, we identified three key concepts to be foregrounded in the teaching of linear equations: (a) equality and the meaning of the equal sign; (b) inverses and inverse operations; and (c) the meaning of solution to an equation. However, many learners experience difficulty in mastering these concepts because they are simultaneously trying to make sense of new mathematics in the form of negative numbers and algebraic symbolism, and many are still trying to master fractions from primary school.

In this paper we propose that linear equations can be introduced through numeric equations such as $5 + 7 = \square - 9$. Such equations promote an equivalence view of the equal sign and introduce learners to concepts of inverses and inverse operations without the burden of dealing with algebraic symbolism. In our literature review we discuss the main sources of learners' errors and difficulties in solving linear algebraic equations. We then provide several tasks involving numerical equations and briefly discuss how each task can promote access to algebraic thinking and to the key concepts necessary to solve linear algebraic equations. We do not provide (yet!) empirical evidence of implementing our proposed ideas.

LITERATURE REVIEW

Our emphasis on numeric equations is underpinned by a view of algebra that is best described as generalised arithmetic (Kaput, 2006) which is constituted by the structural generalisations made from working with properties of arithmetic and from the relation between numbers. While generalised arithmetic promotes relational reasoning, working with generalisations in algebra requires support in the transition from arithmetic to algebra, which is the "space" in which our work sits. Warren and Cooper (2009) concurred with Mason (2008) in the mutuality of relations between generalised arithmetic and algebraic thinking, that is, arithmetic promotes algebraic thinking and vice versa. It follows that the transition from arithmetic to algebra is a gradual one and may take more time than curriculum documents acknowledge and which teaching schedules make provision for. Recent research in South Africa, (e.g. Pournara, 2020) showed that even Grade 9 learners (15 years old) in top-performing state schools have difficulty in solving linear equations with letters on both sides. The learners' errors stemmed more from difficulties in manipulating algebraic expressions and dealing with negatives/subtraction than in executing the standard procedure for solving equations.

There has been more than 40 years of research on learners' approaches to solving linear equations and the errors they make. One common finding is that there is substantial shift in moving from solving equations where the unknown appears on one side only to solving equations where the unknown appears on both sides. This has been referred to as a cognitive gap (Linchevski & Herscovics, 1996) or a didactic cut (Filloy & Rojano, 1989). While this discontinuity is not a focus of our paper, we recognise the importance of preparing learners to deal with equations with variables on both sides of the equal sign by emphasising an equivalence view of the equal sign and introducing ideas of inverses and inverse operations.

Our review of the literature is separated into three sections: approaches to solving linear algebraic equations and the associated errors; aspects relating to algebra such as conceptions of the equal sign and difficulties with basic algebra; and aspects relating to number and arithmetic operations.

Approaches to and errors in solving algebraic equations

Kieran (1981) identified several approaches to solving equations, including undoing or working backwards, trial-and-error substitution, transposing of terms and performing the same operation on both sides. The first two approaches are considered informal or arithmetic methods and can be used for equations with letters on one side. However, trial-and-error is not always an efficient approach even for examples with variables on only one side such as $7c - 3 = 12$, and it will be particularly difficult in solving equations with variable on both sides.

While formal or algebraic methods are necessary to solve efficiently equations with letters on both sides, several errors have been identified in the literature as learners apply these methods. These include: adding a term to one side but subtracting it from the other side; moving a term across the equal sign without changing its sign; applying the incorrect inverse operation, and forcing the expression into the familiar structure of $x = k$ by eliminating "unwanted" terms/coefficients (Kieran, 1981; Pournara, 2020; Sanders, 2017).

Learners tend to over-rely on informal methods such as inspection and undoing because these are adequate for solving linear equations where the unknown is on one side only. Consequently, they may not willingly drop the strategy when moving to equations with unknowns on both sides (Pournara, 2020).

Meaning of the equal sign

Learners' conceptions of the equal sign impact their success in solving equations. Despite this, attention to the equal sign is typically not addressed in secondary school curricula (Banerjee & Subramaniam, 2012; Knuth, Stephens, McNeil, & Alibali, 2006). Research on learners' conceptions of equality initially distinguished two different views of the equal sign: as a do-something signal and as an indication of equivalence (Kieran, 1981). An operational view is typically associated with uni-directional reasoning about the equal sign and can be applied to solve equations of form $ax + b = c$. For example, given $2m - 3 = 5$, a learner might reason 'something multiplied by 2 and then subtract 3 gives me 5?' thus treating the right side as the result of operations performed on the left side. A relational view, where the left side is seen as the same as the right side, is required to solve equations of the form $ax + b = cx + d$. Learners with a relational view of the equal sign also appreciate that changes on one side of the equation affect the other side. This is a core idea in learning equations and can be strengthened early on. Research has shown that learners who demonstrated a relational view of the equal sign were better able to solve linear equations (Knuth et al., 2006), consequently our numeric equations tasks foreground this from the outset.

Errors in operating on algebraic symbols

Learning algebra involves, amongst other things, making sense of new symbols and notation, and research is unanimous that this is difficult (e.g. Kaput, 2006). Therefore, it is not surprising that learners make errors in working with algebraic notation. The conjoining error, e.g. $x + 2 = 2x$ is a typical example of this. Learners need to see expressions such as $x + 2$ as both the process of adding 2 to x, and the outcome of that process. Recent research in South Africa, with Grade 9 learners (15 years old) in four top-performing state schools showed that learners' errors in solving linear equations with letters on both sides were frequently related to difficulties in manipulating algebraic expressions, particularly those involving negatives/subtraction (Pournara, 2020). For example, many learners simplified $5x - x$ to 5 rather than $4x$ which suggests incorrect parsing of the expression where they focus on $x - x$.

Errors with number and arithmetic operations

Many errors committed in the process of solving algebraic equations stem from errors with negatives and subtraction, and with fractions and division.

Negatives and subtraction: The transition from arithmetic to algebra involves expanding one's view of the minus symbol. It can be viewed as an operator (subtraction) or as a sign (negative). Hence when learners encounter an equation such as $3 + 2x = 5 - 4x$, the $-4x$ can be seen as subtracting $4x$ or as negative $4x$. This duality of the minus symbol is a substantial obstacle for learners. Solving equations always involves dealing with negatives/subtraction hence the importance of paying additional attention to signs and operations from the outset. A particularly common error found in our previous research was that of detaching the minus sign (Herscovics & Linchevski, 1994) when learners operate on numbers/terms with a leading negative, e.g. $-2 + 5 = -7$ and $-3x + x = -4x$. In both cases learners detach the minus symbol, isolate it from the expression, perform the addition and re-attach the minus symbol to the answer.

Fractions and division: Learners have difficulty in solving equations with fraction coefficients or using the multiplicative inverse of an integer-coefficient. Initially, getting a fraction as the solution is challenging. For example, a learner may solve $2c = 7$ as $c = 5$ to avoid a rational solution. Equations with fraction coefficients or constants are both difficult, for example, $\frac{3}{2}c - 5 = 11$ or $3c - \frac{5}{2} = 11$. In using the multiplicative inverse, it is difficult for learners to comprehend that dividing by a number is the same as multiplying with its reciprocal.

THE POTENTIAL OF NUMERIC EQUATIONS

Numeric equations are of the form: $a + b = c + d$ where a, b, c, d are integers, and they enable us to pay attention to the equal sign as balance; the properties of numbers and number operations; and using inverse operations. But equally important, numeric equations make this possible without the need to deal with algebraic notation which frees up learners to focus on equivalence and balance without the burden of dealing with like and unlike terms and operating on them. In addition, numeric equations provide opportunity to emphasise the importance of identities, inverses and inverse operations as part of the transition from arithmetic to algebra, in general, and from numeric to algebraic equations, in particular. We will use a place holder (□) for the unknown. Learners are familiar with this symbol from primary school mathematics and may even encounter it in numeric equations at primary school.

Equal sign as a balance: When solving equations, each successive line is an equivalent equation of the previous line while maintaining balance. The equations in each line look perceptually different, but they are equivalent forms, generated by manipulating both sides of the equation using the same operator.

Below is a set of four equations:

A. $5 + 3 + 2 = \square + 4$

B. $5 + 3 + 2 + 7 = \square + 4 + 7$

C. $40 + 5 + 3 + 2 = \square + 4 + 40$

D. $3 + 2 + 5 + 12 = 12 + \square + 4$

To predict the answers: Look for what is the same and different in the equations and write what you expect the value of □ to be.

Figure 1: Task 1, Structure of equation

In the primary school, learners are exposed to binary operations which often lead to over-generalisation that (a) the equal sign indicates "gives me" rather than "the same as", and (b) the final answer after the operation must be a single number. Both overgeneralisations are challenged by focusing on the meaning of the equal sign as a balance and by including operations on both sides. We used variation of example sets to draw learners' attention to the structure of the equations. Consider Task 1, where equations A – D are perceptually different but the value represented by the box is the same. Encouraging learners to think of reasons for why these equations are structurally similar pushes them to see the balancing of left- and right-hand side of the equation. In particular, we want learners to notice the repetition of "$5 + 3 + 2$" on the left and "$\square + 4$" on the right.

The balance meaning of the equation can also be strengthened by evaluating the changes made to the equation using different operators. Consider Task 2, where learners must decide whether the equation will be balanced after performing the specified operations.

$4 + 6 = \square - 2$			
A. Add 5 to both sides	B. Add 2 to the right side	C. Multiply by 2 on both sides	D. Add 7 on the left side and subtract 7 from the right side

Figure 2: Task 2, Balancing an equation

Learners often make the mistake of adding a number on one side of the equation but subtracting it from the other. Tasks 1 and 2 explicitly address this learner error by showing how the value of the box changes when same or different operations are performed on both sides of the equal sign. Another kind of a task is where we can encourage learners to infer based on the given information. Consider Task 3, where learners must predict and then solve the equations.

If you know that $8 - 4 = 7 - 3$, use it to solve these equations:

a) $8 - 4 - 7 = \square$

b) $8 - 4 + 3 = \square$

c) $7 - 3 + 4 = \square$

d) $8 - 4 + 3 - 7 = \square$

Figure 3: Task 3, Inferred equations

Focus on properties of operations: The commutative and associative properties are helpful in manipulating the appearance of the equation which aids equation solving, for example, putting all the like terms together on one side of the equal sign. Building on these properties for whole numbers and examining whether they work for integers helps learners in developing this idea. The properties need to be used for the four arithmetic operations so that learners can flexibly manipulate a numeric equation. Task 4 deals with addition and the commutative property. Task 5 involves multiplication and flexibility with products.

Fill in the missing number to balance the equations.	
a) $4 + 7 = \_\_ + 4$	b) $4 + (-7) = \_\_ + 4$
c) $4 + 7 = \_\_ + 3$	d) $(-7) + \_\_ = 4 + (-7)$
e) $4 + 7 = \_\_ + 2$	f) $\_\_ + 4 = 4 - 7$

Figure 4: Task 4, Using commutative property

Copy and give the value for $\square$ in each equation.

A. $5 \times 4 \times 3 = \square \times 4 \times 3$

B. $5 \times 4 \times 3 = \square \times 2 \times 3$

C. $5 \times 4 \times 3 = \square \times 1 \times 6$

D. $5 \times 4 \times 3 = 5 \times 2 \times \square$

E. $5 \times 4 \times 3 = 5 \times 1 \times \square$

F. $5 \times \square \times 3 = 3 \times 4 \times 5$

G. $10 \times \square \times 3 = 5 \times 4 \times 3$

H. $5 \times \square \times 6 = 4 \times 5 \times 3$

Look at the set of eight equations in Q6 and answer the questions:

a) Note that $\square$ is sometimes on the right as in A to E. What is the product of the numbers on the left in A to E?

b) Sometimes $\square$ is on the left of the equal sign as in F to H. What is the product of the numbers on the right in F to H?

c) So, what should the product be on the sides with a $\square$ in A to E? And in F to H?

Figure 5: Task 5, Using products

In Task 5 we extend to equations with more than two numbers on each side, and we change the position of the unknown so that learners must consider the entire product on each side, and how this changes (or not) from the other equations in the collection. From here, they are expected to deduce the value of the unknown without calculating full products on each side.

Using the inverse relations: While learners are encouraged to use inspection to solve numeric equations, inverse is a key idea in equation solving. Additive and multiplicative inverses are used in all algebraic equation solving, and it is important to link the notions of additive and multiplicative identity with the inverses. For example, using the additive identity, learners can see that the additive inverse of 3 is –3, that $-8r + 8r = 0$, etc. Task 6 illustrates how additive identity is used to reinforce finding additive inverse.

> If we know that $7 + \Delta = 0$, then which of the following statements are TRUE? Give reasons.
>
> A. The value of Δ is 7.
> B. Δ can be any whole number.
> C. The value of Δ is 0.
> D. The value of Δ is -7.
> E. Δ and 7 are additive inverses of each other.
> F. Δ is the additive identity for addition.

Figure 6: Task 6, Additive inverse

Task 7 involves a comparison of inspection and the use of additive inverses to solve a simple numeric equation. Helena's method acknowledges the strengths of inspection, encouraging learners to think about the relationship between the quantities on both sides of the equal sign. However, it may also reinforce an operational view of the equal sign. Nisha's method, as written below, appears more complicated for such a simple equation. Nevertheless, we include it as a simple introduction to the application of additive inverses and a pre-cursor to isolating the variable in algebraic equations.

Look at the equation $5 + 7 = \square + 4$. Helena and Nisha solve the equation in different ways. Both girls find that the solution is 8.

Read their methods carefully. Make sure you can link the words and the statements.

<u>Helena uses *solving by inspection*.</u>	
Helena first works out the value on the side without the $\square$:	$5 + 7 = \square + 4$
she adds the 5 and 7 to get 12.	
She now knows $\square + 4$ must be 12.	$12 = \square + 4$
Helena thinks 'What must I add to 4 to get 12?' to get a value for $\square$.	
Helena gets:	$\square = 8$

<u>Nisha uses *solving using additive inverses.*</u>	$5 + 7 = \square + 4$
Nisha's first step is to simplify $5 + 7$ just like Helena did:	$12 = \square + 4$
Nisha then subtracts 4 from both sides of the equation to get the $\square$ on its	$12 - 4 = \square + 4 - 4$
own. (She uses the *additive inverse* of 4)	$8 = \square + 0$
Nisha then simplifies both sides of the equation to get a value for $\square$.	
She gets:	$8 = \square$
Which is the same as:	$\square = 8$

Look at the equations below:

A. $6 + 3 = \square + 5$ B. $3 + 3 = \square + 1$ C. $\square + 7 = 9 + 2$

a) Quickly work out the answer using Helena's method. Write down only the answers.
b) Now try to solve the equations using Nisha's method which uses *additive inverses.*
c) Go back to your response for equation A. Write what you did in each step and say why you did it.

Figure 7: Task 7, Inspection and additive inverse approaches

CONCLUSION

It is well-known that learners experience difficulty in solving linear equations. Yet, when learning the formal procedure for solving equations, many of their difficulties are not related to the use of inverses and inverse operations. Numeric equations offer a level of structural similarity to algebraic equations without the additional demand of dealing with algebraic simplification. They also provide opportunities to attend to the structure of numeric expressions. This attention to structure has been illustrated by the careful use of variation within the example sets in the tasks. For example, in tasks 4 and 5 we deal explicitly with the commutative and associative laws in the context of attending to structure of numeric expressions. Numeric equations also have the potential to move learners from the over-use of inspection methods to the use of inverses as shown in Task 7. That said, we suggest very careful selections of examples in this regard and we avoid cases such as $2\square + 3 = 11$ and $2\square + 3 = 3\square - 4$ because the idea of "two times box" seems contrived to us and we think it is more appropriate to deal with cases requiring multiplicative inverses once learners are comfortable with the most basic algebraic equations. We fully appreciate the importance of the multiplicative inverse in solving linear equations. However, we suggest that this be introduced once learners are familiar with numeric equations containing "one box".

In conclusion, we propose that greater attention to numeric equations has the potential to assist learners in lower secondary school who are struggling with algebraic notation, to make sense of equations without the distraction of letters. Also, numeric equations have potential to develop a balance view of the equal sign and to move learners beyond inspection methods for solving linear equations at primary school. Of course, this potential will only be realised if there are suitable materials and professional development for teachers. This is the next part of our work – to undertake empirical design research studies which will include teaching experiments where we will act as the teachers, and other instances where practising teachers will implement the materials we have designed.

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RESHAPING MAKERSPACES TO LEARN FRONTIER MAKING PRACTICES

Geetanjali Date[1!], Ravi Sinha[1#], and Sanjay Chandrasekharan[1*]

(All authors contributed equally)

[1]Homi Bhabha Centre for Science Education, Mumbai, Maharashtra, India.

[!]geet@hbcse.tifr.res.in, #ravis@hbcse.tifr.res.in, *sanjay@hbcse.tifr.res.in

School-based makerspaces (MS) offer potential spaces for learning frontier engineering design practices, which could enable students to address current and future societal needs and challenges. In order to explore how school-level MS could be reconfigured to scaffold the learning of frontier engineering design practices, we describe the design process of a frontier making case (Paperfuge). We extract the key engineering design practices in this case, and represent them as an expanding spiral pattern of the design space. We argue that this pattern (shown also in other cases) suggests ways to integrate key frontier making practices into MS. We briefly discuss some of these ways with respect to the current MS pedagogy.

INTRODUCTION

Makerspaces (MS) are building, tinkering, and learning spaces where people from diverse backgrounds work on collaborative or individual projects, learn new skills, hang out with friends, or repair things (Peppler et al., 2015; Vossoughi & Bevan, 2014). Many community-MS also have fabrication technologies such as 3D printers and laser cutters, which allow teams to work on hardware prototypes or even manufacture products in small quantities (Anderson, 2012; Blikstein, 2013; Mersand, 2021). Several companies, colleges, and K12 school settings have on-campus MS, and the Indian government has initiated an ambitious Atal Tinkering Lab (ATL) program, seeding over 7000 tinkering spaces for middle and high school students, with INR 20 Lakhs per school, (approximately 18 million dollars in total) in grants (AIM, NITI Aayog, n.d.). ATL aspires to enable making that addresses the current and future unmet needs and challenges of society (AIM, NITI Aayog, n.d.).

There is a growing interest among policymakers, educators, and researchers about the potential of MS to provide alternate and diverse pathways for building productive STEM identities. Additionally, MS is viewed as a testbed for innovative and emerging ideas, with the potential to foster STEM learning and nurture "neoteric innovators". Researchers have characterized MS practices using constructs such as collaboration through the air, iterative prototyping, feedback, and playful experimentation (Bevan, 2017; Halverson & Peppler, 2018; Mersand, 2021; Sheridan et al., 2014; Sinha et al., 2021; Vossoughi & Bevan, 2014).

As MS supports material-based, hands-on activity, and artifact-building through iterative prototyping, it is a potential space for learning frontier engineering design practices. Recent research argues that learning of practices is as important as learning the body of STEM knowledge (Fields et al., 2017; NRC, 2012). The National Education Policy (MHRD, 2020) emphasizes “Experiential learning within each subject, and explorations of relations among different subjects (p 11)” at Middle and Secondary education stages. It also encourages curricular integration of ‘Essential Subjects, Skills, and Capacities’, including innovativeness, problem-solving, and design thinking (p 15). However, it is unclear how school-level MS could be configured to scaffold the learning of frontier Engineering Design practices.

This paper presents an initial exploration of how school MS (such as ATL) can support the learning of frontier making practices. For this, we first describe the design process of a frontier making case (Paperfuge), which addressed unmet social needs. We extract the key engineering design practices in this case, and represent them as an expanding spiral pattern of the design space. In the discussion section, we argue that this pattern (shown also in other cases) suggests ways to integrate the characteristic frontier making practices into MS, and discuss these with respect to the current ATL-MS pedagogy. We conclude with the potential implications of this analysis for MS researchers, educators and designers.

DESIGN OF THE PAPER CENTRIFUGE FROM PRAKASH LAB

Paperfuge is an ultra-low-cost (20 cents), lightweight (2g), portable, human-powered centrifuge made out of paper, string, and plastic, designed by Saad Bhamla and colleagues in the Prakash Lab at Stanford. A vial of blood sample is attached to the rotating paper disc, like the one in a whirligig/ buzzer toy (see Fig 1 (right)). It can help perform several diagnostic assays, like separation of plasma from blood, to detect diseases like malaria. The design of Paperfuge led to innovations in point-of-care diagnostics, and also generated new theoretical knowledge (analytical solution for the whirligig/buzz toy dynamic system). The design originated from the team's serendipitous encounter with an expensive centrifuge used as a mere door-stopper in a remote health clinic. Since the clinic did not have stable electricity, the centrifuge machine, though needed, could not be put to its designated use. Manu Prakash's team, having designed an ultra-low-cost microscope earlier, decided to tackle the challenge of designing a portable, ultra-low-cost centrifuge that does not require electricity (TED, 2017, 03:18; Rober, 2017, 5:54). We describe the design process as a series of episodes.

Episode 1

As the centrifuge works by spinning, the team began by investigating everyday gadgets such as salad spinners, yo-yos, and egg beaters, among other things, as possible starting points for the design. A closer examination of the feasibility of the solution, based on the requirement for high RPMs, revealed that the whirligig toy may be a potential choice. The other options were bulky, and had low RPM outputs that made the separation time impractical. This led to a preliminary centrifuge design that was a modified whirligig/ buzzer toy (Bhamla et al., 2017:3). According to Saad Bhamla, "This is a toy that I used to play with when I was a kid. The puzzle was that I didn't know how fast this would spin. And so, I got intrigued, and I set this up on a high-speed camera. And I couldn't believe my eyes. This thing, when you heard the noise, was actually going at 10,000 to 15,000 RPM. To me, that seemed like what we wanted to actually make a centrifuge." (Stanford, 2017).

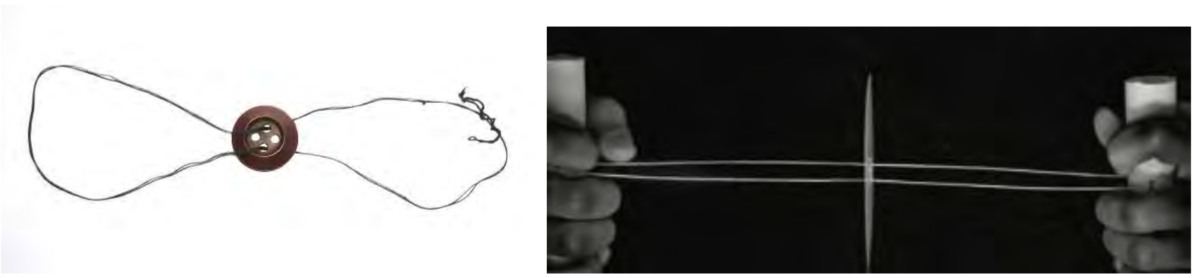

Fig 1 (left) Traditional button whirligig (Wikimedia); (right) Paperfuge (Bhamla et al., 2017)

Episode 2

According to Manu Prakash, "Before us, nobody had actually understood how this toy works. So, we spent a significant portion of this time truly understanding the mathematical phase." (Stanford, 2017). The team developed a detailed theoretical model capturing the extensive parameter-space of the whirligig system. With a disk diameter of 5mm, they were able to achieve 120,000 RPM and 30,000 G forces, for a mathematically calculated RPM of one million. Using experimental data to validate this model allowed them to optimize the dimensions of the components. With a disk diameter of 50 mm, their paper centrifuge spins at 20000 RPM and 10,000 G forces (Bhamla et al., 2017).

Episode 3

Unlike conventional centrifuges that rotate unidirectionally, this design uses a string mechanism, making it an oscillatory system. Rigorous experimentation was conducted to develop custom protocols for different types of assays, to validate the design efficiency and reliability of the buzzer-centrifuge model, as compared to the off-the-shelf standard centrifuges. Bhamla, Manu Prakash, and colleagues (2017) mentioned that the ratio of plasma and blood after spinning for 90 seconds proved to be sufficient to calculate the hematocrit value (that tells whether someone is anaemic or not). Additionally, spinning the Paperfuge for 15 min can separate the buffy coat and can isolate malaria parasites (Bhamla et al., 2017).

Episode 4

The design was improved by incorporating three independent mechanisms to avoid spills during operation. Firstly, the disk had a sandwich model, sealed via Velcro strips to avoid the spill of blood from the capillary at high speed. Secondly, the capillary was chosen to be extremely durable and able to withstand high G forces. Thirdly, capillaries were inserted into "sealed-straw holders" to further avoid accidental leaks. (Bhamla et al., 2017).

Episode 5

The Paperfuge design was replicated with materials other than paper, such as wood and polymer. These were 3D-printed, and explored for applications such as the separation of nucleic acid, DNA etc. Additionally, this process opened up novel avenues to design point-of-care (POC) diagnostics instruments that are versatile, extremely portable, and low-cost. The 3D-printed design is also manufacturing-compatible, as it can be made in large numbers using the conventional injection-moulding techniques.

CHARACTERIZATION OF THE PAPERFUGE DESIGN PROCESS

Based on this reconstruction of the Paperfuge design process from secondary data, we now extract the salient features and practices characteristic of this frontier making practice. Within and across these design episodes, the design process was iterative, and nonlinear.

Problem formulation started with identified unmet need in a particular social context

The team was involved right from *the stage of identifying the social need in its context*, and *formulating the problem that needed to be solved to address this need*. This led to a completely novel design, and not a mere customization of the existing centrifuge machines.

Contrary to this, if the design process had started with theoretical studies of the buzz toy as a dynamic system, and sought to maximize its efficiency, it is possible that a hand-powered centrifuge for medical diagnostics would have never happened. (In an extreme scenario, the optimization would have led to a new weapon design, given the force it can generate.)

Optimization approach in Paperfuge

It is possible that battery-driven portable centrifuge machines could have been designed to address the electricity constraint. But the Prakash lab imagined the Paperfuge functioning in a severely resource-constrained environment, and aimed for a simpler design without batteries. While optimization is usually focussed on efficiency, where the input is minimized, and/ or the output is maximized, the Paperfuge optimization focussed on fitting the available (hand-powered RPM) input to achieve the required output (separation of fluids) by developing time protocols. Performance optimization here was oriented towards and driven by the requirements, and was not a purely techno-scientific efficiency maximization.

Spirally expanding problem scoping

The initial identified need was to spin without electricity. Progressively, the prototype solutions allowed identifying other requirements – time and safety protocols, appropriate capillaries, and manufacturing processes that served the context. These requirements were not purely techno-scientific, and the socio-economic aspects of the context were integral to them. It was probably not possible to identify all the diverse socio-technical requirements in one go and develop a solution. Within every problem-solving episode: i) a need was identified, thus scoping the problem at that level, ii) a complete solution was developed, iii) a broader need became apparent from the prototype, thus expanding the scope of the problem, iv) the prototype was modified to develop a solution to the expanded problem, v) the process continued, to identify more complex socio-technical needs and to design satisficing solutions.

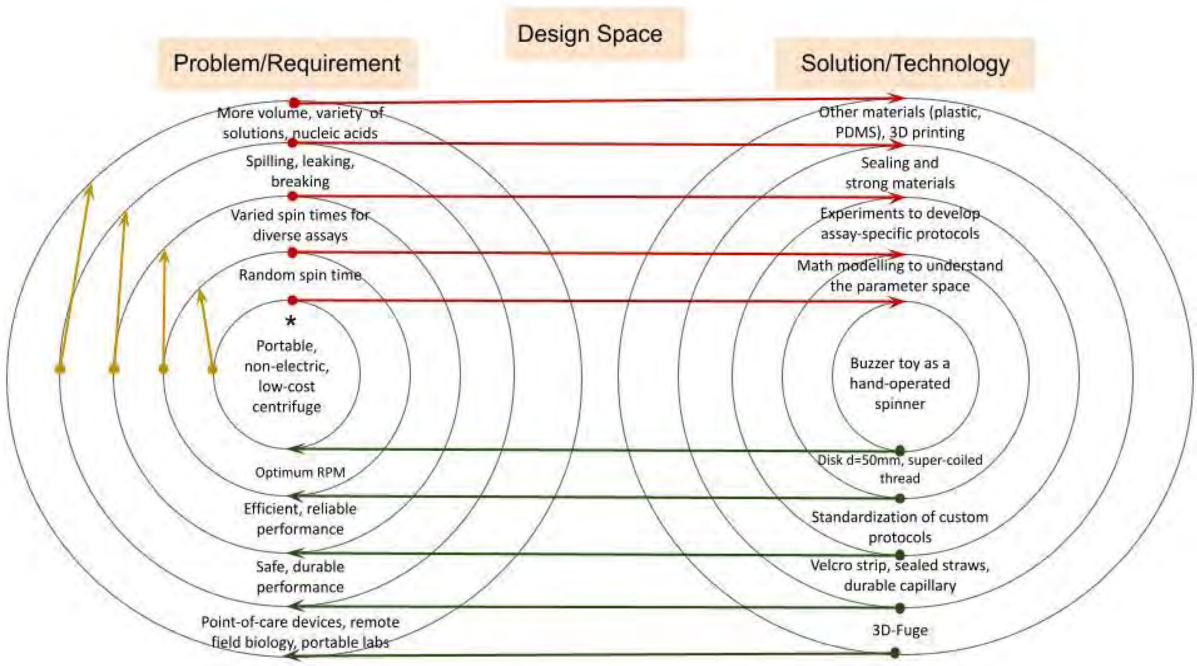

Fig. 2: The expanding spiral pattern of Paperfuge socio-technical design. Left: the problem (top), requirements met (bottom); Right: the solution (top), the technology (bottom). The

spiral starts at the ‘*’ in the left core circle, and traces the arrow sequence Red-Green-Yellow.

Figure 2 represents this process. The design episodes, starting with the first episode at the core of the concentric circles, depict the identified need in the ‘problem/ requirement’ space, and the corresponding technology design in the ‘solution/ technology’ space. The solution feeds into the next need identification, starting an expanded version of the next episode of the problem-solution cycle, and so on. We call this the *expanding spiral pattern of design* space and process. The spirally expanding process allowed for a step-by-step experiential understanding of the solution, in terms of its functioning and performance. It also revealed requirements yet un-addressed by the solution, thus leading to a new innovation cycle in an expanded design space.

Contribution to theoretical understanding

The team, though trained in advanced engineering sciences and modelling techniques, did not start the design process with the theoretical/ formal structures or exact calculations. The design direction was the reverse, with *theoretical understanding extended by the prototype*, in the process of creating one of the fastest spinning human-powered gadgets (Bhamla et al., 2017).

Product and manufacturing are co-designed

Using injection-moulding techniques expands the design space to include mass-manufacturing of the 3D-fuges (3D-printed fuges made of polymers). This allows manufacturing considerations to be a part of the design process, and to manufacture the product independent of any constraints imposed by pre-existing capital-intensive manufacturing facilities. The designers “move all the way from gathering requirements to developing specifications to product design and manufacturing design” (Date & Chandrasekharan, 2018).

DISCUSSION

About their unusual Paperfuge design journey, Manu Prakash says “There is a value in this whimsical nature of searching for solutions because it really forces us outside our own sets of constraints” (Stanford, 2017). Frontier making, where solutions at the cutting edge of science and technology are built, requires stepping outside established engineering, mathematics, labs, factories, manufacturing and business structures.

If makerspaces are to be places where students learn engineering design practices that enable them to do this kind of frontier making, it would not suffice for makerspaces to function around a ‘toolkit’ idea of activities, where students start by learning tools or techniques and end by building what can be built with those tools or techniques, leading to a prototype (mostly proof-of-concept) for a narrowly construed problem statement. Instead, makerspaces need to be places that support students in (ad)venturing out of their classrooms and labs to notice a requirement, and formulate it into a problem they can solve by making, even if it requires devising new tools, techniques, and conceptual knowledge. To do this, makerspaces such as Atal Tinkering Labs may need to expand their purview and pedagogy.

The expanding spiral process of the Paperfuge design, and other similar models reported elsewhere (see Date & Chandrasekharan, 2018, for other examples), indicate that: a) identifying and designing for a primary need comprehensively, and then widening the scope of the need to be addressed, is a key approach to problem-scoping in socio-technical design processes, which is needed to address complex and messy problems; b) eco-social factors can enter the design space, simultaneously with techno-scientific considerations and not later as add-ons; c) multiple cycles are not random explorations, rather the designed prototype/ solution plays a role in the next design episode or cycle.

CONCLUSION

Drawing on this characterization of frontier making, school-based makerspaces could encourage students to identify needs by themselves, rather than work with a given problem statement. If makerspaces focus on scientific concepts and technological tools/techniques alone, students' making will remain limited to, and by, the known techno-scientific. Further, Makerspace activities that expect student making to end in a single iteration would block the imagination role of the prototype. Understanding and enabling a design process like the expanding spiral could allow for overcoming these constraints. Further research would be necessary to operationalize these suggestions into curricular modules, activity structures, and pedagogical scaffolds in makerspaces.

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RESPONSE OF AN OPTICS LAB IN PANDEMIC

Mahima Chhabra[1,a], Ritwick Das[2,b]

[1]Department of Education, University of Delhi, Delhi, India, [2]National Institute of Science Education and Research (NISER), Jatni, Odisha, India

[a]mahima.chhabra@gmail.com,[b]ritwick.das@gmail.com

Pandemic undoubtedly disrupted the 'old style' conduct of the science laboratory courses forcing a sudden shift to online mode leaving institutions in a state of rattle, somehow rising up to the situation. The attempts to provide learners "lab-like experiences" in the absence of access to physical laboratories, have given rise to many creative and novel ways of conducting the class. Although it is too early to evaluate the effectiveness of the methods which evolved during these testing times, a reflection and sharing of these experiences can help teaching as well as the research community. Towards this end, this study aims to document and understand the experiences of students and teachers about an Optics Laboratory course conducted in the online mode as the response to a worldwide Covid crisis.

INTRODUCTION

We are going through unprecedented times. The world went to a standstill with countries after countries getting into 'lockdown' perhaps for the first time in the history of humankind. However human resilience has continued to be as strong as the virus itself. There have been continued attempts to bring life to normal, though the struggle still continues. This pandemic era has been full of irony and extremes. On one hand 'normal' was almost completely disrupted and on the other hand it brought about a lot of shuffle - reshuffle and emergence of 'new normal/s' . This has also been the time where human creativity reached its exemplary height to 'exist' and continue life. Education being one of the fundamental pillars of any country's progress was amongst the first which was revived but in a completely transformed manner. The only possible way to continue seemed to shift from a physical world into a virtual world. Although virtual reality was not new for the globe, the transformation had been extremely gradual, intentional and thus somewhat planned i.e. setting the infrastructure, training personnel and then using tools and mostly incorporating ICT in the pedagogy and then investigating its effectiveness (Brinson, 2015;Usman,Suyanta and Huda, 2021; Hawkins & Phelps, 2013; Darrah, Humbert, Finstein, Simon & Hopkins, 2014;Pyatt & Sims, 2012). However now the shift had to be sudden, rapid and rather forced, as it seemed the only way to continue. With it popped up new challenges to which educational institutions had to respond.

For science subjects as well as those having a practical or field component, the challenge was particularly difficult. For theory, many online platforms such as Google Classroom, Zoom, and Microsoft TEAMS helped with their various features such as breakout rooms and jamboards. However, shifting practical labs and fields to virtual level posed a greater challenge. In this work, the response of an institution that faced the challenge in its face is being presented. Both teachers and students had different experiences and their perspectives have been shared and discussed with implications for the future.

LITERATURE REVIEW

Nurturing 'process skills' is a fundamental learning objective of science. Apart from application of theoretical understanding of the involved concepts it includes various other aspects such as planning or designing an experiment, the procedure to follow, data collection, data analysis, inferring and concluding. All these processes usually happen in a physical lab, in either groups or individually, involving a lot of trials, failures, errors and discussions. Bringing all these experiences online, especially the hands-on experience which is considered a quintessential part of the lab posed a huge challenge to which teachers and authorities adapted in a variety of ways showcasing their concern, effort, creativity and resourcefulness. There were two main responses - in the face of extenuating circumstances many instructors revisited and modified the focus of their learning goals for the lab course, however some maintained them as pre-covid times. Amongst the former there were researchers like Petrou (2021) who emphasised to leverage this situation as an opportunity to strengthen other skills such as proposing a design, a procedure and formulating conclusions which students are weak at (Doran, Chan, Tamir, &. Lenhard,2002 and Wright et al., 2010, Hodson, 2014), since these aspects usually lack attention in physical settings. She also found that students perform better on proposing a procedure and plan in inquiry-based lab activities, when the skill sequence of the task engages their thinking before the “hands-on” part. Within this category there were also instructors who felt that demonstrations of experiments via video could also benefit learners to a great extent. For instance Elkhatat & Al-Muhtaseb (2021) recorded their videos and got them professionally edited for uploading to social platforms such as YouTube. Werth et.al. (2020) in their survey reported that various anecdotal data of the participant teachers supported the finding by Kestin et.al. (2020) that “video demonstrations are more effective learning tools than live demonstrations and that students reported the same level of enjoyment from both”.

Amongst the latter there were those who tried to provide hands- on experience in many ways. Some like Campari et.al (2020) devised simple experiments analogous to those performed in the lab for students of an introductory physics course in biology. Authors reported that “working in isolation at home, even if they [students] were supported online by tutors and teachers, forced the students to think about what they were doing more carefully and deeply than they usually do in the lab”. Many others utilised simulations, for instance Labster was used by Callaghan et.al. (2021) for ‘Discovery’ which is an inquiry-based STEM educational program. Dark (2021) conducted an introductory Optics Lab using Interactive Physics Simulations for plane mirrors and image formation by convex and concave lenses and from Physlet Physics for single slit diffraction, two slit interference, and diffraction gratings. Some like Bradbury & Pols (2020) also resorted to the use of microcontrollers (Arduinos) in a ‘Maker Lab’ course, which resulted in students’ successfully being able to conceive, design and carry out a wide variety of experiments suiting their interdisciplinary interests via open-inquiry projects.

Data Collection was another dimension in which two main categories evolved. First those instructors, who emphasised that students should collect their own data and second who provided their learners with datasets for analysis. Former category coincided with those who lay stress on students’ having a hands-on experience of the experiment- whether it was done using objects easily available at home or purchased online (Campari et.al (2020) or providing learners with kits dispatched to their home (Dark, 2021) or utilising simulations which helped in generation of data. Within this category, another interesting group of teachers were those who became surrogates for data collection, i.e. they were physically present in the laboratory and performed the experiment as instructed by learners and collected data on their behalf, thus providing students remote access and more control (Weiszflog & Goetz, 2021). The latter category of teachers provided datasets to students which were collected by them (Elkhatat and

Al-Muhtaseb ,2021) or the lab staff, or that which was generated by previous batches or in some cases even that which was publicly available (Callaghan et.al., 2021). In this regard, Petrou (2021) in her research found that students who recorded and analysed their own data performed better on conclusion, which was also supported by findings of Klein et. al. (2021) that "physics laboratories were considered the most successful when the students' own data were collected…both for reinforcing the physics content and acquisition of experimental skill" which was in contrast with earlier studies suggesting no significant distortions of epistemic learning processes (Priemer,Pfeiler, & Ludwig,2017) even if the second hand data was evaluated and interpreted .

In most cases, both synchronous as well as asynchronous modes were utilised for conducting lab activities. Many researchers utilised the concept of 'flipped classroom' (Elkhatat and Al-Muhtaseb ,2021; Bradbury & Pols,2020) where the actual experiment was conducted by learners themselves and live class hours were utilised for goal-setting, planning, and evaluating findings (mostly in case of open inquiry) and also in discussions and problem solving. A common concern which surfaced was if students engaged with the material provided in asynchronous mode. One way to addressed this concern was by conducting Pre-lab quizzes to examine students' understanding of the general principles covered in the video (Elkhatat and Al-Muhtaseb, (2021) or presentations (Dark,2021) and another way was shown by Wilcox et.al. (2019) using PlayPosit software to embed questions into the video as part of the pre-lab.

Thus it can be seen from the review that even though the challenge was new, many ways were evolving to tackle the situation and to continue 'learning'. Many of these ideas have also proved fruitful; however, much more data will be required to evaluate their effectiveness.

METHODOLOGY

All the students who participated in the study were in the 5th semester of a 10 semester integrated Master of Science (Int. M.Sc.) program (in physical sciences) at the National Institute of Science Education and Research (NISER), Bhubaneswar. The class had 53 students and all the students had credited all the basic courses in physical sciences that included classical mechanics, quantum mechanics, electromagnetism, statistical mechanics and mathematical physics. In addition, they also credited one basic course on wave-optics as well as electronics. 5th semester includes a lab course that comprises 6 different experiments essentially from the domain of 'Optics' in physical sciences. The experiments covered the fundamental concepts associated with 'propagation' of electromagnetic waves namely diffraction (single-slit/double-slit diffraction), interference (Michelson and Fabry-Perot interferometer) and polarisation (Malu's law and retardation plates).

At NISER, the Int. M.Sc. laboratory courses over 10 semesters in physical sciences are structured in such a way that there is a gradual shift from completely structured inquiry to open inquiry (Tamir, 1991). Thus, in 5th semester, teachers usually try to encourage learners to start thinking beyond the given experiments. For instance, the students are encouraged to ascertain the results if certain experimental parameters are altered in the given apparatus. However, such aspects are kept optional for the course.

During the normal times when offline laboratory classes are scheduled, the laboratory was conducted in three basic steps - Students go through the manual (available in a repository) of the assigned experiment prior to the laboratory class, they performed the experiment as well as collected the relevant data during laboratory class hours which was followed by a detailed analysis which were submitted as lab reports. Finally, the assessment process consisted of evaluation of the reports and an interaction (viva-voce) after each experiment. Due to restrictions imposed by the ongoing pandemic, accessibility of students to physical labs was not possible. Thus the laboratory course was executed in an online mode and instructors adopted the following method.

In the first step, students were provided a set of manuals describing paraphernalia of an experiment such as its objectives, brief theoretical background, and step-by-step procedure to achieve the objective as well as the precautionary measures. The manual also provides an illustrative technique to acquire experimental data.

This was followed by providing students with pre-recorded demonstration videos of each experiment. These videos were recorded capturing important portions of the procedure or apparatus that required elaboration. While recording the videos, the teacher also explained brief reasons for carrying out various steps. The videos for each experiment were shared with the students about a week before the scheduled laboratory class. A few illustrative videos could be found at https://opc.iitd.ac.in/virtual_lab.html. Such an exercise was essentially done to make the students familiar with the apparatus and various aspects of the experiment. The students are expected to read the manual and watch the videos before the scheduled laboratory class.

The third step was a synchronous online student-teacher interaction during the lab class. In this case, two separate video cameras were deployed in the laboratory where one of them was focused on the experimental set-up and the second one faced the teacher. This live session was carried out over a period of approximately two-hours. During the first 30 minutes, the teacher re-introduced the experimental configuration, functioning and a few salient features associated with the measurement of physical quantities such as light intensity, mechanical least count of the instrument etc. This step was taken considering the issue of equitability since many students faced severe accessibility issues. Subsequently, the teacher performed the experiment, which was a demonstration of 'how the steps mentioned in the laboratory manual were being translated into action' and 'what were the possible outcomes'? The remaining part of the laboratory class was dedicated to the discussion with students which also included possible variations in the experiments (within the practical limits) which were being suggested/proposed by the students. The teacher carried out the suggested alterations and displayed the change(s) in the outcome. This also led to further discussion about the plausible reasons for expected as well as unexpected outcomes. Therefore, significant attention was paid to discuss important theoretical concepts in optics and their impact on the experiment. Since, the live interaction took place with all the students in the class simultaneously, there were cross-talks and exchange of ideas amongst the students as well, with regard to manoeuvring the experiment and unexpected outcomes.

In the final step (immediately after the live class), the students were provided with a set of data to quantitatively estimate a physical quantity such as wavelength of light, distances (thickness or width) etc. and analyse the results. 10 independent pre-recorded datasets were randomly shared with the students ensuring that not more than 6 students received identical datasets. Students needed to tabulate the data, analyse and infer the results which they recorded in their practical files and submitted.

A part of the assessment was carried out with the help of an online Quiz consisting of short and very short answer questions using Google Forms after each experiment. Finally at the end of the course 'grand viva-voce' was conducted with each student individually, based on all 6 experiments. Final assessment consisted of the lab reports, quiz and the grand viva-voce.

ANALYSIS

Michelson's Interferometer

In this section, conduct of one of the experiments is illustrated including student- teacher interaction .In the Michelson Interferometer experiment, a set of 5 pre-recorded videos were shared with the students. The teacher explained the set-up which included a laser, a half-silvered mirror (a 50:50 beam splitter), beam expander, compensating plate and a pair of mirrors. Further, formation of circular fringe pattern and associated changes in the pattern when the plates were moved were also demonstrated. These videos focussed on various parts of the experiment but did not explicitly elaborate on the step by step process of the experiment. The procedure was demonstrated and explained in a chronological order in the beginning of the live session. This activity was followed by a detailed discussion. The students raised a variety of questions which were logically and practically argued upon by carrying out suitable and viable alterations in the experimental set-up. For instance, one student asked 'why the distance between dark-to-dark fringes (in the interference pattern) is non-uniform with respect to the centre of the pattern? This observation was made during the live-session as well as in the pre-recorded videos. Likewise, another student questioned the role of beam expander in the experiment. This is essentially motivated by the fact that the beam expander is usually not discussed in the theory class. The teacher subsequently drew students' attention to the size of the laser beam which is approximately 3-4 mm. Further, the teacher asked students to estimate an approximate fringe width given this beam size. This exercise revealed that the fringes would be extremely small for resolving through our eyes. Thus, the beam expander facilitates the observation of interference fringes (and their width) by amplifying the transverse extent of the laser beam. A few students suggested manipulating the setup towards exploring unknown aspects and their impact on the outcome (i.e. the fringe pattern). For instance one student asked, "What if the compensating glass plate was removed?" This point was discussed through an analytical and mathematical framework which essentially revealed that the compensating glass plate was simply compensating for the additional optical path traversed by one beam with respect to the other. However, the most important parameter which determines the fringes in the interference pattern is the 'phase difference'. An additional path traversed in one arm (with respect to the other) would simply physically 'shift' all the fringes on the screen. This would not alter the distance between fringes or it would not affect the collapsing of the fringes at the centre. Consequently, the absence of the compensating plate would not affect the interference pattern significantly except physically shifting the fringes with respect to each other. In order to illustrate this point, the teacher practically removed the compensating plate from the experiment and showed that the interference fringe pattern looked similar to the situation when the compensating plate was inserted in one of the interferometer arms. Another student wanted to explore the change which would result if the laser beam splits in the ratio of 30:70 (or 70:30) instead of a 50:50 set-up. The teacher practically replaced the existing beam splitter with another one which split the beam in the ratio of 30:70. The students could observe the changes on the screen where the contrast between dark and bright fringes reduced with respect to a stanchion when a 50:50 beam splitter was employed. This time, the teacher asked the students to explain this observation. This observation and following discussion helped all the students to appreciate the impact of superposition of light beams which have different amplitudes.

Teacher's Experience

After the semester was over, the teacher (who is one of the authors as well) reflected on his experience which is summarised in this section. He felt that since the students were not performing the experiments physically, the possibility of exploring the instrumentation and experimental design was missing in the online laboratory course. Nevertheless, the gap was compensated by focusing on building crucial interconnects between the theoretical underpinnings with the experimental observations/outcomes. The discussions during the live interaction sessions also focussed on ascertaining outcomes of unexplored/unprescribed experimental steps. It allowed all the students to simultaneously explore finer intricacies and a few underlying physical aspects through questions and answers. The discussions also included those manifestations which necessarily need not have a direct connection to optics as such. This is a novel feature which happened during the online live interaction session. It also facilitated a better insight into the theoretical concepts and connection with experimental instrumentation. This feature was revealed in the quizzes as well as interaction during viva-voce. Thus as a teacher he viewed it as an opportunity to strengthen theory-practical interconnect and conceived it as the main focus.

Students' Experience

After the completion of the laboratory course, the students were requested to provide a feedback, which is summarised in this section.Students were asked to rate their experience of this particular laboratory course in the online mode, for which most of them (92%) responded on the positive side, ranging from Good to Excellent (Fig.1). However, when it was asked to compare the online mode to offline mode most students (88%) still prefer the physical (offline) laboratory classes (Fig.2).

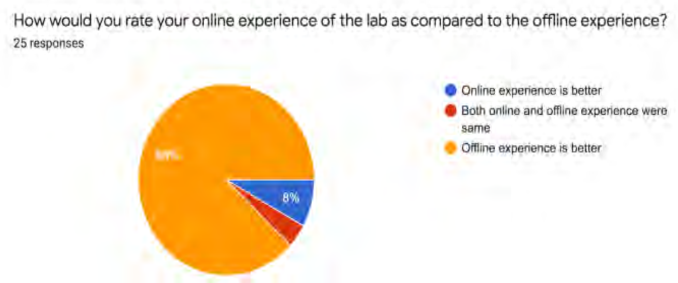

Fig. 1: Experience of online mode of Optics Lab course

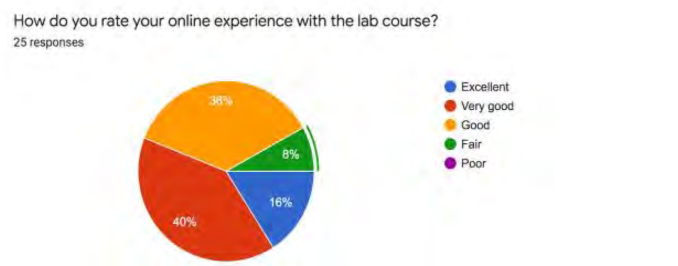

Fig. 2: Comparison of online mode and physical mode for Lab Course

Further, the students were asked to share their overall feedback about the present lab course (in online mode). There were quite a few common themes which emerged from their responses which are summarised in Table-1. The students were also asked for suggestions to improve their online laboratory experience; and features (if any) of the online mode which they would like to be carried to physical (offline) laboratory classes. Their responses are summarised in Table-2 and Table-3 respectively.

Themes with approximate % of responses	Students' Representative Comments
Explanations of the experiment were effective and useful (40%)	*Sir explained all the things excellently* *It has been the best lab course in my 5th semester in terms of what I learnt as a direct result of the effort and coordination between the faculty, scientific officers, and the lab assistants.*
Video Demonstrations were highly appreciated (50%)	*The best thing I liked was that we used to have the recorded demonstration before the lab day. They were really deep and full of knowledge.* *I enjoyed the online lab. The video that was sent beforehand was very helpful in gaining prior knowledge about the experiment. The live demonstration of the lab experiment was also brilliantly done*
Quiz and Viva	*The quizzes helped a lot in understanding and strengthening the concepts* *The quizzes were pretty much like a theory course - Linear Optics 2? If possible, this course can be turned into a 4-credit theory-cum-lab course. The "grand" viva was extremely good, a very interactive and enjoyable session* *I was extremely pleased to have the viva session at the conclusion of the course*
Theory- Practical Connect	*As we had taken a theory course of optics, it helped understanding a lot of things without difficulty.* *Knowledge of theories of the experiment beforehand helped me to understand the workings clearly.*
Missed the hands-on experience	*We don't know how to operate different instruments* *the experience we get by handling the equipment is incomparable with online labs* *I prefer offline mode as I felt having hands on experience with the equipment is absolutely necessary, and for me learning through mistakes and then correcting them was the most helpful in previous labs*

Table 1: Overall Feedback about the optics lab course

Suggestions for improving online lab experience	Students' Representative Comments
Camera and video	*Some improvement in camera quality if possible*

quality can be improved (16%)	*By increasing the video quality of uploaded videos* *More organised and well prepared videos(can be substituted with YouTube videos)"*
Increased student involvement (8%)	*Students involvement needs to increase* *Increase students' involvement in experimental details, like some sudden verbal questions just after explaining an experiment will force students to stay online/be attentive, which is another problem in online lab* *One thing that can be done is to ask questions throughout to students to keep them engaged*
Simulations (20%)	*Various simulations of the experiments are available free online webpages. These can be used or referred to students so that they could understand the working on their own. Also I think data could also be gathered from there.* *Maybe by including some kind of simulations that can be performed by us- like to have a virtual hands on experience on the lab work. Like setting up the instrument and taking observation and then calculation. Though it won't be as effective as physically setting the experiment setup.* *Use virtual reality. Holograms if possible.*
Quiz and Viva a. Nature of the quiz can be modified b. Number of Quiz can be less (12%)	*It would be better to ask more open-ended questions and grade them considering how innovative and feasible their approach is, so that we are encouraged to think in different and innovative methods for the problem.* *It would be a good idea to have 2-3 quizzes instead of 6 (questions for multiple experiments could be mixed together). Along with that, it would be perfect if we were asked to show our work on paper that we did while solving questions, to reduce the scope for malpractice.* *Weekly viva instead of weekly tests* *If the viva will be taken after each experiment, it will be better*
Constant feedback for improvement (8%)	*It would have been helpful if the corrected lab reports were shown regularly so that necessary improvements can be made.*
Focus of Demonstration (8%)	*Demonstrations could be a bit more data oriented showing how some data points are gotten. More emphasis on how to use the equipment.* *A demonstration could be made for aligning the spectrometer.*
Novelty	*I think it would be even more exciting for students if experiments similar to "diffraction produced from ultrasonic wave" which uses a different and innovative method for creating diffraction in comparison to the previous experiments are included. This encourages us to think out of the box.*

Table 2: Summary of students' suggestions for improving online lab experience

Features which could be carried from online mode to physical (offline) mode	**Students' Representative Comments**
Simulations (4%)	*If some kind of simulations can be done (I know it's very difficult), but that's how students can have some experimental knowledge"*
Demonstrations (video) (52%)	*A video demo of the experiment shared before performing the experiment will help a lot. So, it can be adopted in offline mode as well.* *Live online demonstration by instructors is very much necessary or at least they should take a small half an hour or 15 minute class about how to operate, what's the aim of the experiment, why we're investing our time in it and the theory behind the experiment and better to clearly teach the procedures and the pros and cons. Without this component, offline labs become technical suffering which is okay for engineering students but not for science students.*
Demonstration and Explanations	*You not only explained the experiment well beforehand, but also made us think about subsequent changes in the experiment so that we can learn better. It was good for handling some things easily which would save time and avoid wastage of resources by some mistakes (mistakes that barely teach anything new).* *Maybe a small demonstration of the experiment with the theoretical explanation(through videos) before the actual labs can save time in the lab and give us more time for performing the experiment.*
Explanation	*It would be better to share a short video (even the ones recorded for our batch) of the experiment which explains some theory also before the starting of labs, so that students can explore further into the topic while doing the lab* *The explanation of the setup was more clear in the online mode than offline*
Online Report Submission	*I believe that the mode of submission of reports was the best thing to emerge out of the 5th semester*
Video recording of class	*The other good feature was the ability to revisit recordings of classes as per my convenience* *Recordings of the lab [classes] may help in case someone is absent*
Others	*Computerised data collection methods* *Making a soft copy of notes while teaching offline with the help of a projector* *The quizzes were a good part of the online labs.*

Table 3: Summary of students' suggestions about features which can be carried from online mode to offline lab mode

DISCUSSION

The restrictions due to the Covid-19 pandemic had an adverse impact on laboratory classes. In the present context, the Optics Laboratory course which is a core course for the 5th semester students of Int. MSc. program at NISER, was carried out in an online mode. Although the change in mode was cataclysmic, yet the documentation of the experiences reveals interesting insights. The teacher's attempt was to provide experience to the students, which could be closest to that obtained for a physical laboratory within the limit afforded by the resources (including material as well as time). The responses revealed that the students' experiences were encouraging to an appreciable extent. None of the students rated the online experience to be poor; rather most of them (92%) expressed it to be a positive step. The recorded video demonstrations turned out to be one of the most appreciated aspects of this online course. Students pointed out that prior knowledge of the experiment facilitated easier understanding in the live/online class. Even the teacher was of the view that it helped students get into deeper meaningful discussions during the live sessions as illustrated in the section 'Michelson Interferometer'. The students went on to suggest continuation of video demonstration even in post-Covid offline classes (which are to be conducted in physical mode). This response was a significantly intriguing for us as researchers. Students' wish to see a demonstration of how the experiment is done before actually doing it seems against the spirit of 'learning by doing' which is stated to be the primary goal of a laboratory. This also compels us to think about the reasons for the same. One possible explanation could be the long socialisation in the education system of 'doing the experiment in the right way' (which is usually the result of a common misconception about the method of science), and 'getting the right results'. However, the discussion with the course instructor provided another perspective. The instructor was of the opinion that even if students had a prior look at the process of experiment, it does not ensure that the students will be able to perform it successfully. According to him, accomplishing an experimental work requires optimally operating/using the device/set-up for obtaining the required outcome which could be drawn as an analogy with learning how to drive a car. Videos on how to drive a car may not teach driving but can definitely provide mental clarity and better understanding about various features of a car. Though it is difficult to conclude about students' reasons for recorded videos, this insight has nevertheless opened up a direction for further research into the belief system of students as well as the teachers regarding 'learning in laboratory'. It further leads us to think more deeply about the learning objectives of a laboratory and the potential role of this new media within this domain.

The students' responses further revealed that 40% of them agreed upon the teachers' detailed explanation (i.e. step by step procedure of the experiment) and drawing its linkages with the theoretical concepts both in the demonstration as well as the live classes was very helpful. Many students also appreciated the coordinated effort made by the faculty, scientific and technical staff to make online experience a possibility. A few of them also highlighted that in physical (offline) mode, long durations of time were spent to understand and explore the technicalities of experiments. One of them remarked, "It was good for handling a few things easily which would save time and avoid wastage of resources by some mistakes (mistakes that barely teach anything new)". This again made us ponder over what meaning students are making of 'wastage of resources" and "mistakes barely teaching anything new", which further impels us to relook at our intended objectives - is our aim that students should discover the linkages between theory and practical aspects on their own? or our explicit explanations are providing them better clarity and deeper understanding of the concept? And if so was it an unattended gap already existing in our physical system? The discussion sessions in the live classroom were also well appreciated by learners. The teacher's intention was clear in making these sessions geared towards generating questions rather than oversimplifying. Since this laboratory course is placed in the middle of their journey from structured laboratory to an open-ended laboratory practice, the teacher made attempts to garner more suggestions from students regarding trying newer techniques or exploring other possibilities. This effort was duly acknowledged by the learners as well "the teacher made us think for subsequent changes in the experiment so that we can learn better".

Although learners were acquainted with quizzes, viewing them as a part of a lab course was a new experience. Many found them to be an enriching experience which fostered a theory-practical connect. Some of them also suggested inclusion of open-ended questions as a part of the quiz and be graded on the basis of innovation and feasibility of their approach for problem solving so that they are encouraged to think in different and innovative routes. Interestingly, the learners could look at the potential of the quiz to test more than intended i.e. foster creativity, which is highly appreciable. One of them also suggested incorporating space in the quiz format to show the process they adopted for problem solving so that their understanding could be reflected and 'malpractices' could be prevented. A few of them suggested reducing the number of quizzes conducted and one of them was keen to replace it by viva-voce type interaction. Students also reported good experience of the final viva-voce.

As per the teachers' experience, the shift of focus for using the lab to strengthen theoretical understanding seemed to have been fulfilled to a great extent. Although the students' responses in quizzes and viva-voce are not being presented here, the teachers' experience has been somewhat ratified by students' experience as many of them explicitly stated significant improvement in their conceptual understanding. A course on optics followed by a lab course in this mode has mutually helped in conceptual understanding as well as understanding of the experiment.

Although the online experience has certainly been positive and helpful for most students in multiple ways, it cannot replace the experience of a physical (offline) laboratory. This feeling was mutually shared by the teacher as well as the majority of students (88%). Most of them missed the hands-on experience of handling the instruments. One of the main suggestions of incorporating simulations for improving the online experience was also motivated from the wish to operate instruments and collect their own data. Also, the students were missing their active engagement during a lab class. An inevitable consequence of online mode is the absence of many organic experiences such as dynamic social interaction, expression of students' body language when they understand or not understand certain aspects/concepts. We are virtually together but not together at the same time and technical limitations lead to monotony along with a sense of passiveness in the online class also termed as "zoom fatigue" by Etkina et al. (2010), which both students and teachers realised. Thus, a few students did suggest ways to increase the involvement of learners by asking frequent questions by the teacher. A few suggestions were aimed towards better use of technology such as high-resolution cameras and 4K videos to facilitate procedural clarity. Furthermore, as the students visualised videos to be long term resources for the lab, some suggested having them recorded by professionals and turn them into shareable recordings via social media platforms such as Youtube. Some students also found the flexibility of using the recorded material (both demonstrations as well as the class discussion) very useful since it could be used at their own pace and could be revisited as per their convenience.

CONCLUSION

Overall experience of conducting the lab in the online mode in the given format has certainly helped deepen the theoretical-connect to an experiment and thereby, improve the conceptual understanding of associated concepts, which happened to be the focus of the instructor. Nevertheless, in case the situation demands the institutions to continue in the online mode, this study shows that there is a good scope of incorporating many more features to improve the online experience. However, it could be safely asserted that the laboratory class in an online mode (in the present form) would not be a replacement for a physical hands-on experience laboratory.However, a few aspects of the online laboratory course, on the other hand, could be carried to the physical (offline) mode for enriching the students' experience.

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STEAM EDUCATION FOR SCHOOL TEACHERS IN NEPAL

Indra Mani Shrestha[1, a, !], Bal Chandra Luitel[1, a, @], Binod Prasad Pant[1, a, #], Niroj Dahal[1, a, $], Netra Kumar Manandhar[1, a, *]

[1]Kathmandu University School of Education, Hattiban, Lalitpur, Nepal

[a]he/him/his

[!]indramani@kusoed.edu.np., [@]bcluitel@kusoed.edu.np, [#]binod@kusoed.edu.np, [$]niroj@kusoed.edu.np, *netraz@kusoed.edu.np

Since the integrated curricula were implemented in grades 1-3 in Nepali schools two years back, there is still a chaotic situation among school stakeholders (headteachers, teachers, students, and parents). Being graduated with discipline-based education and teaching a particular subject for years, teachers are still not able to grasp integrated teaching and learning. In this context, we felt that we as responsible citizens decided to promote STEAM education throughout the nation so that maximum schoolteachers, especially in remote areas, would be empowered. After recapitulating and reconceptualizing our learning and experiences, we encountered a common issue of teaching and learning having been raised by teachers and students for a long time - Can we teach and learn all subjects, especially science and mathematics, using the arts-based pedagogy – storytelling, poetry, singing, and dancing? Subscribing to this pertinent issue, we conducted STEAM workshops for schoolteachers across the nation in Nepal. Using collaborative autoethnography as a research methodology, we analysed and interpreted that STEAM education approaches engage teachers and students in creative teaching-learning activities. Further, arts-based pedagogy is an empowering pedagogy for teaching and learning all subjects in an integrated way. More specifically, arts-based pedagogy helps both teachers and students in self-motivation, creativity, imagination, and critical thinking.

TEACHING AND LEARNING IN THE NEPALI CONTEXT

Elsewhere, Nepali educators, Luitel (2003, 2009, 2013, 2019, 2022), Pant (2015, 2019, 2022), Shrestha (2011, 2018, 2019, 2022), Dahal (2017), Manandhar (2018, 2021) have constantly been raising an issue of disengaged, disintegrated and discipline-based teaching and learning practices in the Nepali context due to culturally decontextualized science and mathematics educations. With the collaborative efforts of our university and the Ministry of Education, Science and Technology (MoEST), the curricula from grades 1-3 were reformed into integrated curricula and implemented since 2020 in all schools.

Since the implementation of integrated curricula, there has been a chaotic situation among school stakeholders (headteachers, teachers, students, and parents) for not grasping the intent of integrated approaches to teaching and learning. The unpreparedness of both stakeholders and MoEST and the COVID-19 pandemic played crucial roles in boosting the chaotic situation further across the nation. When the whole nation was fighting to implement the integrated curricula, our university was running the virtual classes of Master, MPhil, and PhD in STEAM education efficiently and effectively. Since we had been teaching, educating and researching integrated curriculum since 2019 via the university programmes, workshops, training, seminars, conferences, and paper writing via both physical and virtual modes, whichever possible, we collected feedback from our students (pre-service and in-service schoolteachers) and other students, teachers, educators, researchers, parents, and ordinary people across the nation about the intent of integrated curriculum via survey, formal and informal discourses, and informal interviews. The survey report showed the urgent need for Teacher Professional Development (TPD) on integrated approaches to curriculum, pedagogy, and assessment.

In this context, our university took initiation from our side. It began to educate teachers and headteachers from across the nation on integrated approaches to curriculum, pedagogy, and assessment through STEAM Education programmes both physically and virtually. We have been conducting free webinars on STEAM Education every Saturday from 5:30 PM – 7:30 PM (visit https://www.youtube.com/channel/UCy6R6fFPlfVEl8Qvo4UHwgw). This platform is especially created for our university graduates who present their activities, research papers, discourses on STEAM Education to educate all the interested people worldwide. Apart from this, we have been conducting on-demand workshops and Training of Teachers (ToT) programmes nationwide.

Given the above contexts, we have been conducting STEAM Education workshops and ToT for schoolteachers from Basic Level (grades 1-8) and Secondary Level (grades 9-12). Therefore, in this paper, we have presented the narratives on our experiences of conducting STEAM Education and workshops and the outcomes of the study using collaborative autoethnography as research methodology.

STEAM EDUCATION IN SCHOOL EDUCATION OF NEPAL

Both teachers and students must be able to think and act creatively and innovatively for our future generations to address the global challenges (Huser et al., 2020). STEAM Education plays a vital role through multidisciplinary, interdisciplinary, and transdisciplinary integrations of Science (S), Technology (T), Engineering (E), the Arts (A), and Mathematics (M) in curriculum, pedagogy, and assessment, where Science is for inquiry, Technology for skills, Engineering for design thinking, the Arts for creativity and imagination, and Mathematics for computational, logical thinking and problem-solving skills. Referring to Susan Riley, an Arts Integration Specialist, STEAM is an educational approach to learning that uses Science, Technology, Engineering, the Arts and Mathematics as access points for guiding student inquiry, dialogue, and critical thinking (elearning.tki.org.nz).

Many educators in Nepal (e.g., Luitel, 2009, 2019, 2022; Pant, 2015, 2019, 2022; Shrestha, 2011, 2018, 2019, 2022; Dahal, 2017; Manandhar, 2018, 2021) and across the world (Taylor, 2018; Taylor & Taylor, 2019; Goldberg, 2016; Dietiker, 2015; Eisner, 2002; Sinclair, 2001, etc.) have been raising an issue that the roles of arts – liberal arts (narrative, storying), visual arts (images, paintings, sculpture), performing arts (role play, drama) – in teaching and learning all subjects, especially science and mathematics, are not well acknowledged, and hence they are advocating the integration of the arts in school education. Moreover, the integration of the Arts into STEM education places learning into a context, creating opportunities for innovation, teaching flexibility using the Arts to teach students how to solve real-world problems by combining Science, Technology, Engineering, the Arts and Mathematics (Hayman, 2017). The fundamental reason behind the integration of arts is to create "aesthetically-rich learning environments as those that enable children to wonder, to notice, to imagine alternatives, to appreciate contingencies and to experience pleasure and pride" (Sinclair, 2001, p. 26). As Eisner (2008), a leading arts educator, explains: the Arts are concerned with expressiveness, evoking emotion, generating empathic understanding, stimulating imagination that disrupts habits of mind and creates open-mindedness, and eliciting emotional awareness.

Since arts-based pedagogies draw upon holistic experiential learning and constructivist approaches where learners mine their personal experiences to produce situated understandings, these pedagogies open up spaces for exploration, dialogue, and questioning (Carroll, 2018). Arts-based pedagogy, or arts integration, is a pedagogical approach that uses one or more art forms (e.g., visual arts, music, drama, or dance) to deepen understanding and support non-arts and arts curricular learning objectives in the classroom (Lee, 2015).

In this context, the main of the paper is to explore the contributions of STEAM Education programmes that we have conducted for schoolteachers and related people across the nation.

THEORETICAL REFERENTS

As teacher educators, we realized that there is no “royal road” to pedagogy, and grand theories of teaching and researching may not be appropriate in developing ourselves (and teachers) as change agents (Pant et al., 2020). Therefore, we employed Transformative Learning Theory (Mezirow, 1991) and Living Educational Theory (Whitehead, 2008) which are much helpful as our home-grown theories.

Transformative Learning Theory provided us with the new ontological, epistemological and axiological grounds in research that advocates research as a means for transformative learning (Pant, 2019). Ontologically, it helped us shape our ‘being’ by integrating different worldviews into our worldviews to transform our ‘being’ into our ‘becoming’ through critical self-reflection. Epistemologically, our ‘instrumental knowing as being’ was transformed into ‘communicative knowing as becoming’ through transformative learning theory so that axiologically we could widen our horizon of knowing as a synergy of instrumental knowing and communicative knowing for promoting transformative pedagogy.

Living Educational Theory guided us in researching and answering a question of the kind ‘How do I improve what I am doing?” with the implications that include the generation and sharing of a valid explanation of our educational influences in our own learning throughout the study. Whitehead (2008) explained that a living theory is an explanation produced by individuals for their educational influence in their own learning, in the learning of others, and in the learning of the social formation in which they live and work.

RESEARCH METHODOLOGY

We used collaborative autoethnography as a research methodology. Autoethnography is an approach to research and writing that seeks to describe and systematically analyse personal experience to understand cultural experience (Ellis et al., 2011). Moreover, as collaborative autoethnographers, we challenged our personal biases, positioned our research to make sense to a wider audience and had a greater impact on them. We recapitulated and reconceptualized our experiences of promoting STEAM Education programmes and analysed and interpreted them to make meaning out them.

ENGAGEMENT IN THE FIELD

For about four years, our engagement in the field brought many transformations in us, our university education, teachers, headteachers, and students across the nation. The most interesting story was that the majority were interested in arts-based pedagogy.

Remarkably, 2020 and 2021 were engaging for us because the Curriculum Development Centre had implemented the integrated curricula in grades 1-3 nationwide, and we were on-demand for educating schoolteachers nationwide. We would make plans and move towards the destinations for conducting workshops and ToTs for schoolteachers. We present some exciting narratives we experienced during 2020 and 2021 regarding integrated curriculum and STEAM Education.

> "Sir, this integrated curriculum is merely a new book with old ideas. Yes, one thing is easier for teachers as the integrated themes are collected in the textbooks of grades 1, 2 and 3, and we don't need to create themes ourselves."

This was a common understanding of integrated curriculum for many teachers across the nation, especially in the remote areas when a pre-test was taken before the workshops. Moreover, many teachers (and even some headteachers) were found to have a misconception about the integrated curriculum implemented by the government across the nation. They have been teaching integrated themes using disciplinary approaches as they had been doing for a long time. This suggested that many teachers and headteachers still have in their hearts and minds the disciplinary egocentrism – a state of thinking and performing certain tasks where a person is hegemonized with the particular disciplinary knowledge system and ways of developing such knowledge (Connor et al., 2015).

> "Oh, my goodness! I was wrong! It's not a textbook … it's an integrated way of teaching and learning using multidisciplinary, interdisciplinary, and transdisciplinary approaches … We should encourage students to create themes and learn through project-based learning … Oh! We should engage students collaboratively for inquiry learning … Students themselves construct knowledge through social interaction, and we should not impose our methods on them … I promise I will teach accordingly …"

This was the post-test feedback given by the teachers and headteachers after the workshops. We would engage teachers and headteachers in developing various teaching-learning activities based on project-based learning, collaborative learning, constructivist learning, inquiry-based learning using multidisciplinary, interdisciplinary, and transdisciplinary approaches to curriculum integration (Drake, & Burns, 2004). Moreover, curriculum integration centres the curriculum on life itself rather than on the mastery of fragmented information within the boundaries of subject areas. Curriculum integration, in theory & practice, transcends subject-area and disciplinary identifications (Bean, 1995).

> "In the STEAM Education, S stands for Science, T for Technology, E for Engineering, A for Arts, and M for Mathematics. So, we should teach our students these five subjects in school ... But how can we teach students to become an engineer from an early grade?"

This was the pre-test understanding of many teachers before the workshops. They would think STEAM education is about teaching these five subjects in school but didn't know that STEAM education is an integrated approach to curriculum, pedagogy, and assessment. However, after the workshop, they realized that all subject teachers could use Science as/for inquiry, Technology as/for skills, Engineering as/for design thinking, the Arts as/for creativity, critical thinking, and imagination, and Mathematics as/for computation, logical thinking and problem-solving.

> "Oh, my goodness! Being a mathematics teacher, I can teach mathematics using arts-based pedagogy. I will use storytelling, poetry, singing, dancing, and drams in teaching mathematics."

> "I now realized why students hate mathematics and science the most! It's because there is no arts in them, no stories, no poems, no songs, no drama."

Moreover, we have been engaging schoolteachers in developing arts-based teaching-learning activities of all subjects using their local stories, poems, songs, dance, drama, (visit https://www.youtube.com/channel/UCwwY5wIzgvDMCPI-RtKmpHA).

CONCLUDING REMARKS

Our efforts of educating schoolteachers and headteachers via workshops, seminars, webinars, ToTs, conferences, and university programmes have been empowering many accessible and inaccessible people across the nation in STEAM Education. In the latter part of our experience, the growth in the enrolled students in our university programmes (Master, MPhil, and PhD in STEAM Education) has also showed that there is a growing demand of STEAM Education approaches to curriculum, pedagogy, and assessment throughout the nation. Not only that, though there is still a fear of post-COVID-19 across the nation, many community and institutional schools have constantly been demanding us for STEAM workshops. Therefore, our experience of promoting integrated STEAM Education programmes across the country is exemplary in the context of Nepal in terms of educating many schoolteachers, headteachers, students, parents, education committee members and community people. Our survey report showed that STEAM Education approaches have been helping teachers and students to connect school education with real-world contexts.

Finally, we experienced that STEAM education approaches engage teachers and students in creative teaching-learning activities. Our analysis and interpretation showed that arts-based pedagogy is an empowering pedagogy for teaching and learning all subjects in an integrated way. More specifically, arts-based pedagogy helps both teachers and students in self-motivation, creativity, imagination, and critical thinking.

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TEACHERS' KNOWLEDGE OF STUDENTS' THINKING INFERRED FROM LESSON PLANS IN LESSON STUDY

Shikha Takker[1,a,!], Lisnet Mwadzaangati1[2,a,#], Craig Pournara[1,b,*], Jill Adler[1,a,^]

[1]University of the Witwatersrand, Johannesburg, South Africa

[2]University of Malawi, Malawi

[a]she/her/hers, [b]he/him/his

[!]shikha.takker@wits.ac.za, [#]lisnet.mwadzaangati@wits.ac.za, [*]craig.pournara@wits.ac.za, [^]jill.adler@wits.ac.za

Teachers' knowledge of students' thinking has been defined variously in terms of anticipating student conceptions, enabling opportunities for learning, participation in authentic activities while teaching, and so on. Underlying these definitions is a shared understanding that teachers' knowledge of students' thinking lies at the interface of content and students' learning. This specific component of teachers' knowledge can be inferred from written instructional products, particularly lesson plans. In this paper, we infer teachers' knowledge of students' thinking through an examination of written lesson plans created during one cycle of theoretically driven lesson study focusing on promoting geometric reasoning among secondary school mathematics teachers in Malawi. Our findings show that what is "in focus" for teachers is: expected student responses; coherence of the lesson in terms of students' and teacher activity; and generalisation to empirical proof. What is "out of focus" is how to build on different student responses and supporting links between empirical and deductive proof. We conclude by reflecting on how to draw teachers' attention to the latter aspects in the next cycle of the lesson study. The paper contributes to the literature on developing the knowledge base for teaching, through an analysis of written instructional resources.

BACKGROUND AND CONTEXT

We begin with an anecdote from a lesson in geometry from Grade 9 classroom in Malawi. The lesson focuses on the relation between interior and exterior angles of a triangle.

T: When we talk of interior angles, these are angles in a triangle, that are found inside a triangle. And when you talk of an exterior angle, it's just opposite of inside. So, exterior angles are found outside a triangle. Can we have anyone come on the board here to draw a triangle for us and indicate exterior angles?" [Exterior angles drawn by two students are reproduced in Figure 1.]

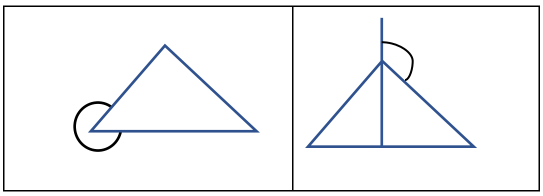


Figure 6: Exterior angle drawn by students (reproduced)

The anecdote above depicts how a teacher elicits students' responses on identifying the exterior angle of a triangle, after providing its definition. The teacher invites the students to mark an exterior angle on the board and does not erase students' incorrect depictions (shown in Figure 1). She continues to revise her definition based on the students' responses.

The classroom anecdote depicts several aspects of teachers' knowledge of students' thinking (TKST), including but not limited to, recognising how students interpret the phrase, "angles found outside the triangle" and representing it as a figure, dealing with a variety of student responses, and developing the correct understanding of the exterior angle. A teacher plans a sequence of tasks following from the definition to strengthen students' understanding of identifying an exterior angle in figures with different orientation and levels of complexity, for example, an exterior angle which is an interior angle of another triangle. As teachers become experienced, they tend to anticipate different student responses and ways of dealing with them, in their planning.

A discourse that valorises student-centred learning has seeped into the Malawian curriculum documents, as it has in many countries in the sub-Saharan Africa. Teachers are encouraged to move from traditional practices to those which involve active student participation, engaging them in group tasks and problem-solving activities which also require more student talk (Ministry of Education Science and Technology (MoEST), 2020). While we note the warning from Tabulawa (2013) that student-centred approaches have failed in sub-Saharan Africa because they do not align with the dominant culture and social structures, we choose to support teachers as they strive to increase student participation in their lessons.

Student-centred mathematical practices require teachers to know about students' mathematics and their learning trajectories. In an earlier study, Takker (2021) characterised TKST as topic-specific including teachers' engagement with the affordance of prior knowledge that students bring to the setting, linking representations aligned with the selected contexts of use, and explicitly planning how to build on students' developing understanding. In this paper, we infer TKST through a study of four lesson plans prepared during the first cycle of lesson study (LS) focusing on improving the quality of geometry teaching among secondary mathematics teachers. The lesson study was driven by the Mathematics Teaching Framework (MTF) (Author, year) derived from the analytical framework on Mathematics Discourse in Instruction (MDI), described in detail later. In MTF, learning is mediated through key teaching practices, one of which is learner/ student participation. Participation is defined as what students will do and write in response to the tasks posed to them and what they will say, using the explanatory language that they are expected to learn. Adler and Ronda (2016) noted that student participation has been backgrounded in the work done with MDI and consequently MTF, which has focused on algebra and functions. We use the lesson study as a context for developing the student participation aspect of MTF in the context of geometry learning. Geometry teaching and learning has been a domain of concern in Malawi (MoEST, 2020) and internationally (Sinclair et al., 2016). In geometry, diagrammatic representations and examples in which tasks are embedded are similar or closely aligned. In this paper, we focus on how teachers planned to engage students in the examples and tasks selected for the teaching of a theorem on the relation between exterior and interior angles of a triangle. Teachers' planned actions are used to infer their knowledge of students' mathematical thinking.

TEACHERS' KNOWLEDGE OF STUDENTS' THINKING

Teachers' knowledge of students' thinking (TKST) has been a focus of several professional development (PD) initiatives in the recent past. In an early attempt to unpack TKST, Carpenter et al. (2000) conducted a research-based PD programme, Cognitively Guided Instruction (CGI).

CGI focused on making teachers aware of the topic-specific students' strategies in arithmetic problem types. Ball, Thames, and Phelps (2008) proposed TKST as Knowledge of Content and Students (KCS). KCS includes predictions about what students will find interesting, motivating, easy or difficult, and hearing and interpreting students' emergent and incomplete thinking. TKST has been characterised depending on how a teacher interprets and responds to students' contributions (Brodie, 2014).

Research in the last few decades has focused on identifying concrete manifestations of TKST. In Ma's (2010) study, an interview item requested teachers of US and Japan to deal with a common overgeneralisation made by students about the relation between area and perimeter. Aligned with Shulman's (1986) initial conceptualisation, Ma found that teachers need to be aware of the key ideas within a topic and how these connect with the structure of the discipline. Much of the work on teacher noticing (Sherin, Jacobs & Philipp, 2011) has focused on identifying the mathematical potential of students' utterances and using them in teaching. Ball, Thames, and Phelps (2008) assert that teachers need insight and understanding of the content to identify students' errors and select appropriate representations for dealing with them. Through reflection on her teaching, Lampert (2010) offers a more nuanced description of TKST by qualifying it as listening to student strategies and seeing their mathematical potential in the social setting of the classroom.

TKST has been promoted through several PD settings. In CGI, the knowledge of student strategies emerged from the research on students' thinking on arithmetic problem types and was offered to the teachers through PD workshops. Teachers' changing talk in these workshops along with their classroom practice were indicators of their developing TKST. Brodie (2014) encouraged teachers to focus on student errors in a professional learning community and mapped changes in teachers' foci. She noted three kinds of shifts in teachers' engagement with student errors, namely, (a) from identifying to interpreting errors; (b) from interpreting to engaging with them; and (c) from focusing on student errors to their own teaching. Teacher learning about TKST has been conceptualised in other PD initiatives where teachers and researchers collaboratively engaged in improving students' learning (for example, Takker, 2021). In the Japanese version of lesson study, teachers create, test, and revise their research lessons by anticipating students' strategies and detailing ways of dealing with these in their written lesson plan (Fujii, 2014). In a recent study, Corey et al. (2021) argued that TKST is a guide to instructional decisions made by teachers during planning and that an analysis of written instructional products is useful in creating a shared knowledge base for instruction.

In this study, TKST is analysed through an examination of lesson plans, and is characterised as teachers' anticipation of mathematical actions that students will perform and the planned ways in which teachers will mediate these actions. The mathematical actions refer to what students will *say*, *write*, and *do* while engaging with a task. The main research question and the sub-questions are:

1. What can we infer about teachers' knowledge of students' thinking from an examination of lesson plans developed in the context of a lesson study?
    a. What kind of mathematical actions are planned for students' engagement?
    b. How do the teachers plan to mediate these mathematical actions?

THEORETICAL FRAMEWORK

With the aim of capturing the discourse[8] in different kinds of mathematics classrooms but particularly focused on those characterised by direct teaching, Adler and Ronda (2015) proposed the analytical framework to capture Mathematics Discourse in Instruction (MDI). MDI is rooted in the socio-cultural perspective of Vygotsky, which implies that teaching and learning is goal directed, and hence focused on a particular object of learning (OoL) (Marton, 2015). While MDI was used to describe the quality of mathematics that was made available to students in South African classrooms, its equivalent Mathematics Teaching Framework (MTF) was developed as a resource to work with mathematics teachers during professional development, including the planning, observing, and evaluating of lessons in LS. MTF evolved as an ideational resource including reified ideas about mathematics, mathematics teaching and mathematics lessons, thus making it a boundary object for use among teaching and research (Adler, 2021). MTF focuses on three mathematics teaching practices to bring the OoL (or lesson goal) into focus for learners: *exemplification* (examples, tasks and representations), *explanatory communication* (word use and naming), and planning opportunities for *student participation*. The extent to which these practices align with the lesson goal indicates coherence in a lesson.

In this paper, we focus on *student participation*, which in the context of lesson planning means thinking about what students will *say*, *do* and *write* during the lesson enactment, and what kind of opportunities are provided for the students to participate. The connections between the knowledge or skills that students are expected to learn, the sequencing of the task and the quality of students' participation, and students' mathematical actions; are indicators of coherence in a lesson. Through this paper, we attempt to elaborate on the student participation aspect of the MTF which until now has been relatively under-described. The nature and form of students' participation might vary culturally, and therefore studying what teachers know about diversity in students' thinking and how it used in planning and enacting a lesson is important.

METHODOLOGY

In Malawi, LS has been introduced recently in PD with primary mathematics teachers and teacher educators (see Fauskanger, Jakobsen & Kazima, 2019 for details). We build on the theoretically driven LS conducted by Adler and Alshwaikh (2019) in South Africa for the topic of algebra, to organise a LS in Malawi on promoting geometric reasoning. The participants were experienced secondary mathematics teachers from two schools in Malawi. The PD began with a two-day workshop, where teachers were introduced to MTF and the process of lesson study with a focus on geometry teaching. In the workshop, there was a discussion on what students will *do*, *say*, and *write* during the lesson. After the workshop, teachers met in their respective schools to identify a teaching problem that they would want to investigate in LS. The teachers planned a lesson (LP1a) and invited inputs from the facilitators. The lesson plan was revised (LP1b) and enacted in the classroom (T1), where one of the teachers taught the lesson and the other teachers from the same school observed. Teachers met after school to reflect (R1) on the lesson plan and the first teaching, where one of the authors was present for the discussion. The teachers replanned the lesson (LP2), taught it in class (T2), and reflected (R2) on it. Teachers then revised the lesson plan (LP3) as part of the LS process. A summary of the first cycle of the

[8] In MDI, classroom discourse is defined using what counts as mathematics in a classroom community. The discourse includes explanations: mathematical and non-mathematical; particular or localized and generalized; their grounding in rules, conventions, procedures, definitions, theorems, etc.; and their level of generality.

lesson study is presented in Figure 2. In this paper, we use an analysis of four lesson plans: LP1a, LP1b, LP2, and LP3 to understand how teachers from one school planned students' mathematical activity and its mediation while keeping the lesson goal in sight.

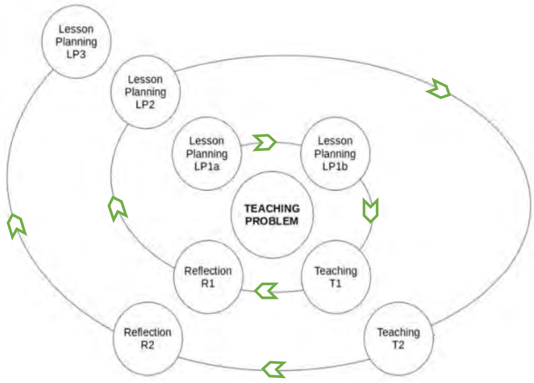


Figure 2: Lesson study cycle

In Malawi, structurally a lesson plan includes the (a) success criteria, which we call the lesson goal; (b) teaching, learning and assessment resources such as charts, mathematical sets, calculators; (c) introduction to the lesson; (d) developmental steps; (e) conclusion; and (f) lesson evaluation. However, the teachers had to add research questions to their lesson plans as these were developed for LS. In the sections on introduction and developmental steps, columns on teacher activity, student activities and learning points are stated, which can be roughly considered as teacher, student and content as identified in the instructional triangle. We focus on the developmental steps to analyse how students' mathematical activity was planned for each task and how teachers planned to mediate it. A summary table with observations for the constructs of interest was created for each lesson plan for the purpose of analysis (Table 1).

Constructs of interest	**Summary of LP1a**	**Observations**
Lesson goal	Learners establish the relation between exterior and interior opposite angles. Calculate interior and exterior angles.	The lesson goal is defined in terms of students' achievement at the end of the lesson.
Teacher activity	a) Measure angles for a given set of triangles, bring out the relationship, discussion, and consolidation. b) Give students triangles with letters as angles, ask them to formulate equations. c) Calculate the measure of exterior angle. Continue the exercise for triangles with different orientations and missing values.	Letters are used to mark angles in triangles. Students measure the angles and fill the boxes. □+□=□ **Tasks** include finding the angle measures, identifying the relationship between exterior and interior angles, and calculating the measure of exterior angle for given numerical measures.
Student activity	Measure angles, establish the relationship, formulate equations, calculate angles.	Students will *measure* the angles in given triangles, *identify* the relation between interior and exterior angles of a triangle, and *use* this relation to calculate the measure of exterior angle for given interior angle measures.

Table 1: Summary of Lesson Plan 1a (LP1a)

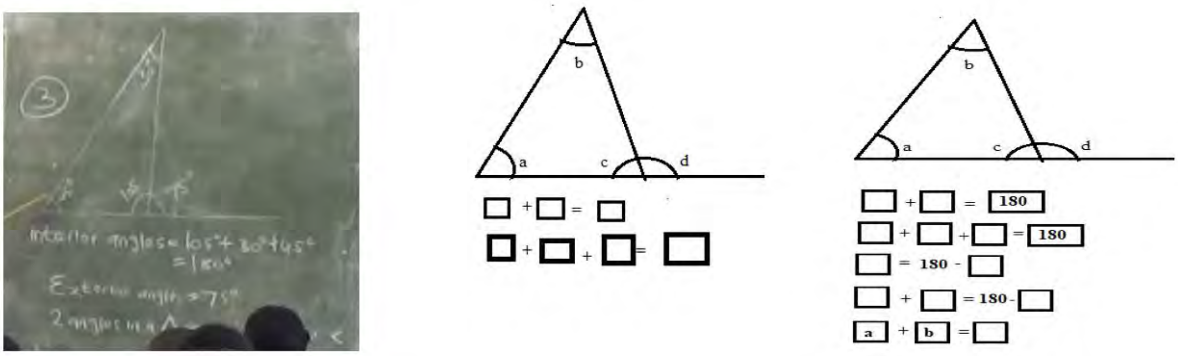
RESULTS

The results section is organised around three key changes in teachers' lesson plans, namely, research questions (RQs), quality of students' engagement in the task and the nature of teacher mediation. These changes are significant in unpacking TKST.

In all the four lesson plans, teachers defined the RQs in terms of students' learning, that is, what students will be able to *do* at the end of the lesson. However, we noted a change in the framing of the questions from a focus on students' learning to how teachers will enable students to learn the relation. For example, in LP1a, the question focused on how students will identify the relationship between exterior and interior angles of a triangle. With inputs from a PD facilitator the teachers added another research question in LP1b which focused on their role. In LP2 and LP3, the teachers dropped the first research question and only asked, "how do we help the learners to see and understand the relationship between an exterior angle and two opposite interior angles of a triangle?". The changing focus of the research question from how students learn to teacher mediation is an important learning as it reflects development in teachers understanding of the role of LS. We note that the change from LP1a to LP1b was initiated by the PD facilitator while the change from LP1b to later plans was initiated by teachers' noticing a variety of students' responses to their explanations for example, when defining exterior angles (refer to Transcript 1 in the introduction) and by recognising that the tasks and examples for answering both research questions were the same.

We noticed a change in the planning of students' engagement with the task across lesson plans. The task demand changed from asking students to empirically generalise the relation between exterior and interior angles using numerical measures, to using the properties of angles formed by the straight line and the sum of the interior angles of a triangle for the given measures to write an empirical proof, and then to writing a deductive proof. The first task in all the four lesson plans invited students to measure the angles for a given set of triangles using a protractor, which constituted students' prior knowledge. In the second task, students were expected to identify the theorem on the relation between exterior and interior angles of a triangle through the empirical activity, which was the first goal of the lesson (see Table 1).

In LP1a, students were expected to formulate numeric equations after finding the measures of angles in the given triangles to empirically generalise the relation between exterior and interior, we call this *empirical generalisation* (see Figure 3). In LP1b, following the empirical generalisation, students were expected to do the *empirical proof*, by finding the angle measures and formulating equations which represented the properties of supplementary angles and angle sum of a triangle to generalise the relationship between the exterior angle and the two interior opposite angles. In LP2 and LP3, students were expected to do the empirical generalisation, empirical proof, and the *deductive proof* using properties to structure the proof (see Figure 3).



(A) (B) (C)

Figure 7: (A) Empirical generalisation, (B) empirical proof, (C) deductive proof
(*Source*: Teachers' original drawings)

Consequently, students' intended mathematical activity shifted from *measuring* and *identifying* the relationship through generalisation, to doing the empirical and then deductive proof using properties of the geometric objects (relation between angles in a triangle and angles on a straight line) in focus. The change in task engagement was initiated by the facilitators and one teacher from the school who drew the group's attention to the connection between empirical generalisation and proof.

The teachers' planned role in LP1a and LP1b was to elicit students' responses to different tasks to "bring out" and "consolidate the relation" between exterior and interior angles (see Table 1). While teacher elicitation continued across other lesson plans, their mediation become more structured. For the empirical generalisation and proof, teachers provided students with a set of equations in which to place the angle measures, such that, the relation between exterior angles and interior opposite angles of a triangle becomes visible (see Figure 3B). Similarly, when writing the deductive proof, teachers provided the structure of the proof and asked the students to fill in the missing blanks (see Figure 3C). The structure of the equations and the naming of the angle measures using letters afforded the opportunity of using the properties of geometric objects in focus, before dealing with the tasks on applying the theorem. We also noticed other changes in teacher mediation in the lesson plans, such as changing the standard orientation and simple diagrams to different orientations and complex diagrams along with the detailed structuring of the task. Lastly, while in LP1a, LP1b and LP2, teachers identified what students will be able to *say* correctly in response to teachers' elicitation, in LP3, a new column on "predictions" was introduced under the section on student activity to account for what students will say that might be partially correct, incorrect, or correct. This change might be initiated by a variety of student responses to tasks such as the introductory task on defining exterior angle (see Transcript 1) and the emphasis on anticipating a variety of student responses in the PD.

The analysis of changes in research question, students' planned engagement with the task, and teacher mediation led us to infer what is "in focus" for teachers, and therefore TKST. In LP1a, LP1b and LP2, teachers are anticipating only correct student responses which are aligned with the goal of the lesson, that is, empirical generalisation of the relation. In LP3, teachers are beginning to broaden their anticipation to include different kinds of students' responses. Second, teachers' mediation is shifting from eliciting students' responses to deriving a theorem from empirical generalisation to using an empirical proof and then a deductive proof although the first task on generalisation from numerical measures is still in focus. However, the link between the empirical generalisation, empirical proof and the deductive proof needs to be brought into focus for teachers and students.

CONCLUSIONS AND DISCUSSION

In this study, we investigate TKST through an analysis of four lesson plans prepared by teachers as they participated in a theoretically driven LS. We note that the changes in the lesson plans in terms of student mathematical activity and teacher mediation manifest in the structuring of the tasks planned for students' engagement, a finding also from Corey et al. (2021). An analysis of the four lesson plans suggests that what is "in focus" for teachers is expected student responses and the coherence in terms of students' and teacher's explanation within a specific task. What is "out of focus" is how to build on different student responses and link the empirically developed proof with the deductive proof. We understand that TKST is guided and constrained by teachers' own knowledge of the content required for teaching, in this case, the need to link the empirical to deductive proof. This linking is important in creating a mathematically coherent lesson, where the sequencing of tasks in the increasing level of complexity is supported by the connections across them. This finding implies that teachers must appreciate the need for deductive proof in geometry and design tasks to engage students in producing such proofs. We, the facilitators of the lesson study, learn from this cycle that teachers need support in understanding (a) what kind of generality is promoted through extrapolation from a set of examples with numerical measures, (b) why is this generality limited to the selected set of examples, that is, the constraints of empirical proving, and (c) the need for deductive proof. Additionally, what it means to engage students into the mathematical activity of proving needs strengthening particularly in terms of anticipating a variety of student responses and examining ways of dealing with them.

We conclude with the potential implication for an analysis of lesson plans towards creating a shared knowledge base of supporting TKST. The lesson plans developed in the context of a lesson study are detailed through the process of collaboration among knowledgeable professionals and are therefore rich in capturing a variety of students' responses and deliberation on ways of dealing with them. Such a lesson plan, which is enriched with research inputs and revisions based on reflections from teaching has the potential of being a shared resource, an artefact with the potential for creating a knowledge base for supporting teachers and teaching.

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LIST OF REVIEWERS

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