epiSTEME - 10

International Conference to Review Research on Science, Technology and Mathematics Education

Extended Abstracts

Homi Bhabha Centre for Science Education, TIFR
Mumbai, India
January 3-6, 2025

Editors
Mayuri Rege
Mashood K K
Adithi Muralidhar
Sathish C G
Krishnendu Kundu

EXTENDED ABSTRACTS

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https://episteme10.hbcse.tifr.res.in/

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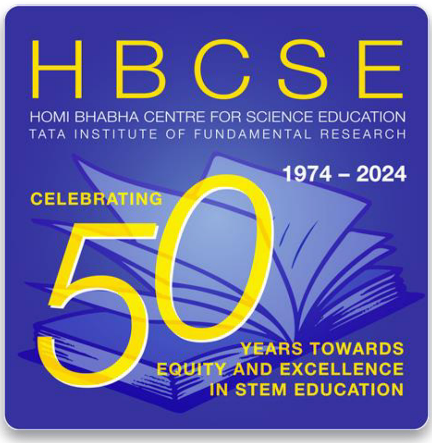
2024: Golden Jubilee Anniversary of HBCSE



HBCSE has completed 50 years striving for equity and excellence in STEM education. 2024 marks the golden jubilee of the Centre. Over these five decades, HBCSE has transformed itself from a well-regarded, but locally-operating and NGO-like entity to a National Centre of TIFR with a gamut of activities in STEM education across the country. It is the nodal centre for the country's premier STEM programmes including the Science Olympiads, the National Initiative in Undergraduate Science, and Vigyan Pratibha. To commemorate this milestone, several activities were held throughout the year, all of which have showcased in part, our achievements and vision for the future. These events have brought together experts, scholars, and practitioners to reflect on the past and explore new possibilities.

As part of our golden jubilee celebrations, we are now pleased to present epiSTEME10, the 10th edition of HBCSE's flagship biennial conference. This event marks not only a significant academic milestone but also a testament to our continued commitment to advancing knowledge and fostering collaboration. We look forward to the inspiring discussions and insights that will emerge from this occasion.

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We dedicate the epiSTEME10 Conference to the memory of
Prof. H. C. Pradhan (30.6.1946–26.12.2024),
former director of HBCSE whose visionary contributions to
science education and mentorship continue to inspire us.
His legacy will always remain a guiding light for the HBCSE community.

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PREFACE

The epiSTEME conference 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 nine 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 nine editions of the conference are available at https://www.hbcse.tifr.res.in/academic/episteme-conference

The focus of epiSTEME 10 is Discipline Based Education Research. The discussions are centered around the rapidly changing nature of scientific research practices, and the implications of this ongoing change for science, engineering, and mathematics education. Many teaching/learning practices that were taken for granted are now running the risk of becoming obsolete, given the rapid change in frontier scientific research practices, such as the building of machine learning models. It would thus not be far-fetched to say that science education is facing a serious crisis. Recent national education policies – such as the National Education Policy (NEP) 2020 in India and the Next Generation Science Standards (NGSS) in the US – seek to incorporate frontier scientific research practices in educational curricula. By bringing together scientists, science education researchers, policy makers and teachers, epiSTEME 10 aims to advance this pursuit.

Broadly, the conference is organised under the following three strands

STEM Workforce Development
Theme 1: Classroom/ Laboratory interaction and discourse
Theme 2: Assessment and evaluation
Theme 3: Professional practice and development of teachers
Theme 4: Educational initiatives and innovations

Cognitive and Affective Studies in STEM Education
Theme 1: Modelling in STME
Theme 2: Knowledge representation
Theme 3: Affective aspects of learning
Theme 4: Problem solving, learning and reasoning
Theme 5: Language and learning

New Media and STEM
Theme 1: Role of ICT in teaching-learning
Theme 2: AI and STEM education
Theme 3: Interdisciplinary STEM education and Design thinking
Theme 4: Visuo-spatial thinking

The conference features eight review talks and one keynote lecture from leading scholars around the globe on some of the key themes mentioned under the above strands. In addition, researchers from across the world will be presenting papers and posters. In total, epiSTEME10 received around 101 submissions from 8 different countries (Bhutan, India, Iran, Ireland, Mauritius, Nigeria, Russia, United States of America). All submissions were sent to at least two reviewers working in related areas for double blind reviews. The list of reviewers is included in this booklet. We thank all the reviewers for their scholarly remarks which we hope helped the authors significantly improve the quality of the abstracts. We accepted 80 extended abstracts, out of which 58 registered for the conference. Of these, 27 papers will be presented in the oral mode and the other 31 in the poster mode. We sincerely thank all the reviewers for their time and expertise in reviewing the abstracts for epiSTEME10.

Organising this conference has been a collective effort, and it takes the collaboration of many dedicated individuals and teams to bring such an event to life. We thank members of the Academic Committee for advice and encouragement and the Local Organising Committee. In particular we thank the Centre Director, Prof. Arnab Bhattacharya, Dean, Prof. Savita Ladage, and faculty members Prof. Aniket Sule, Prof. Deepa Chari, Prof. Ankush Gupta and Prof. Anwesh Majumdar for their support, guidance and encouragement. We greatly appreciate the contribution from all the members of the academic committee and local organising committee for the conference. In particular, we thank (in alphabetical order): Aaloka Kanhere, Akshat Singhal, Akshi Chauhan, Ann Joji, Anupama Ronad, Devendra Mhapsekar, Gajanan Mestry, Gaurav A. Girnar, Gauri Tawate, Harita P. Raval, Harsha Malhotra, Hemant M. Mandlik, Indrani Das Sen, J. B. Waghmare, Krishna Chandra Sahu, Manish S. Thakur, Meena Kharatmal, Milind G. Shinde, Mohamed Hakif, Mukul Mhaskey, Navaneetha M. R., Nishtha, Pragati Dandekar, Prasad C. Mhatre, Praveen P. Pathak, Priya S. Mudaliar, Priyadharshni Elangaivendan, Rajasree Kundu, Rani Prasad, Rashmi A. Shrotri, Ravindra N. Sawant, Rencita Jeslin Pinto, Rupesh P. Nichat, Sandhya R., Santosh L. Rasam, Saurabhee Huli, Shallu Nanda, Shirish R. Pathare, Shweta S. Naik, Sonali S. Dhuri, Srikanth Banda, Sumana V. Amin, Swapnila K. Desai, Swapnil Shejwal, Umesh V. Shenoy, Vaishnavi Mahadik, Vikrant Ghanekar, Vishal Dhavle, Vishrut Yogesh Patel, and Yogita S. Patkar. We also thank the entire computer, administrative and technical staff for their help in various crucial organisational aspects of the conference. We express our gratitude to the members of canteen staff for taking care of the catering arrangements, and to the cosmetic, garden and security staff for ensuring a welcoming and safe environment for all participants.

We thank Manoj Nair for his help in setting up the conference website, paper submission portal and the payment gateway. Our heartfelt gratitude to Adithi Muralidhar for her exceptional efforts in meticulously compiling the abstract book and for her creative design of the HBCSE souvenirs. Our sincere thanks to Sathish C G and Krishnendu Kundu for their diligent coordination and management of the double-blind review of all submitted abstracts, including the thoughtful selection of reviewers.

We thank our sponsors, the Tata Institute of Fundamental Research (TIFR) and Department of Atomic Energy (DAE) and co-sponsors, the Mathematics Teachers' Association (MTA (I)), Indian Association for Physics Teachers (IAPT), Association for Chemistry Teachers (ACT) and Association for Teachers in Biological Sciences (ATBS) with whom the epiSTEME 10 conference was jointly organised.

Mayuri Rege
Mashood K. K.
Co-Convenors, epiSTEME10
https://episteme10.hbcse.tifr.res.in

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Patterns in Mathematics and Nature and Their Uses in Pedagogy

Manjul Bhargava

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We discuss recent work in making the teaching and learning of science and mathematics more hands-on, integrated, interdisciplinary, and multidisciplinary, by making use of the multitude of beautiful patterns that exist all around us and in our daily lives. We'll discuss specific examples from mathematics and beyond mathematics.

About the Speaker

Prof. Bhargava is recognised internationally as one of the foremost mathematicians of our times and one of the leading experts in number theory, a branch of mathematics in which he has made several pioneering breakthroughs. His research includes foundational contributions to arithmetic statistics and to the theory of quadratic and higher degree forms, number fields, class groups, and ranks of elliptic curves. Bhargava is the recipient of numerous awards for his mathematical contributions, including the SASTRA Ramanujan Prize and the Clay Research Award in 2005, the AMS Cole Prize in Number Theory in 2008, the Fermat Prize and the Infosys Prize in 2012, the Fields Medal in 2014 and the Padma Bhushan in 2015. He is a member of the American Academy of Arts and Sciences (2017) as well as a Fellow of the Royal Society (2019). Bhargava is also well-known for his contributions to the public popularisation of mathematics, and held the first Distinguished Chair for the Public Dissemination of Mathematics at the National Museum of Mathematics in New York in 2018. He is the co-chairperson of the National Syllabus and Teaching Learning Material Committee (NSTC) that is tasked with developing school syllabi for Classes 3 to 12 in line with India's National Education Policy 2020.

Biology Education for Sustainable Living in a Fast-Changing World: How, What and How Much to Teach?

L. S. Shashidhara

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It is vital that both the current and future generations are better equipped to address the problems of rapid urbanisation, degradation of natural habitats and impact of climate change on food, nutrition, health and environment. Research-integrated science education aimed at deeper understanding of living systems across scales and its innovative applications is key to provide sustainable solutions for those problems.

The New Education Policy (NEP) of India envisions transforming India into an equitable and vibrant knowledge society, by providing high quality education to all. The NEP sets itself a high goal to prepare our youth to meet the diverse national and global challenges of the present and the future. But students (and their parents) want education that helps them to acquire skills and thereby get lucrative jobs. It is unethical to force students to learn an imposed curriculum only aimed to achieve certain national interests. The balance act requires adopting appropriate pedagogical methods aimed at helping students to (i) develop analytical and critical thinking abilities to generate and verify knowledge/solution to a problem, (ii) innovation skills to connect knowledge to solve real-life problems and (iii) self-learning ability to continually improve their knowledge and acquire necessary skills to address newer problems of their time and/or better and sustainable solutions to perennial problems.

Learning is more effective when students are challenged to identify the cause and effect of a problem that they can relate to their life. For example, climate change is both a problem to be addressed and a problem that can be adopted for more effective teaching. As any biological phenomenon manifests diversely depending on locations/contexts or impact of climate change varies from place to place, innovative educational resources should be locally rooted in their context, but globally relevant for their science.

With this background, I will discuss a few ideas on how, what and how much to teach biology.

My talk emphasises:

1. Groups of teachers collaboratively developing pedagogical tools as per the classroom diversity and needs as peer-interactions are more effective for improving the quality of teaching.

2. Full time researchers/Subject experts may provide external support to teachers for better conceptual understanding of foundational and advanced topics.
3. Entrepreneurial teachers among the teaching community should be facilitated to develop lesson plans for their own teaching and video resources for others to emulate (not to imitate). They may be provided additional training to train other teachers. Such "Training the Trainer" model is better for expansion of innovations in pedagogy.
4. In Biology, with better understanding of the concepts of evolution, students can learn all other topics with ease. Often on their own. At the same time, they will acquire other necessary skills such as enquiry, analytical/critical thinking and innovation. Therefore, much emphasis should be given to teach evolution and all topics in the context of evolution.

About the Speaker

Shashi did his undergraduate and post-graduate studies at the University of Agricultural Sciences, Dharwad, India and Ph.D. at the University of Cambridge, UK. Shashi specialises in Genetics, Molecular Biology, Evolutionary biology, and cancer biology. He is known for his studies on how various organs are positioned precise locations in our body and the precise control mechanisms by which our organs grow to specific size. An outcome of his work has implications to understand cancer, which is a disease caused by the uncontrolled growth of body cells. For the past 7 years, he is working very closely with clinicians on ways to improve outcomes of cancer treatment.

Shashi is a SSB Prize Awardee, an elected fellow all three Science Academies of India, an elected member of European Molecular Biology Organisation (EMBO). Prof Shashidhara has served in the past as Vice-President of Indian National Science Academy (INSA) and Secretary General of the International Union of Biological Sciences (IUBS). During 2019-2023, he served as President of IUBS.

Shashi has also been involved in the promotion of science and science education. He has facilitated training of more than 10,000 school and undergraduate teachers in India on inquiry-based teaching and learning. At IUBS, he is closely involved in policy research on global change and zoonosis. Shashi conceived and initiated the TROPICSU project of IUBS, which is an international project on Climate Change Education.

Facilitating Thinking and Learning In and Beyond the Physics Classrooms Using Research-Based Approaches

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I will discuss, using my research in physics education, how research can be used as a guide to develop curricula and pedagogies to improve student understanding of introductory and advanced concepts as well as for making physics learning environments equitable and inclusive. For example, we are developing research-based learning tools such as tutorials and tools for peer instruction to improve student understanding of quantum mechanics. I will also describe our research studies that provide guidelines for how to enhance physics by making it inclusive. For example, I will discuss how a field-tested short intervention was implemented at the beginning of a physics course and how it improved the performance of traditionally underrepresented students in introductory physics classes compared to the comparison group.

About the Speaker

Chandralekha Singh is a Distinguished Professor of Physics in the Department of Physics and Astronomy and the Founding Director of the Discipline-based Science Education Research Center (dB-SERC) at the University of Pittsburgh. She is a Past President of the American Association of Physics Teachers. She obtained her bachelor's and master's degrees from the Indian Institute of Technology Kharagpur and her Ph.D. in theoretical condensed matter physics from the University of California Santa Barbara. She was a postdoctoral fellow at the University of Illinois Urbana Champaign, before joining the University of Pittsburgh. She co-led the US team to the International Conference on Women in Physics in Birmingham UK in 2017. She is a Fellow of the American Association of Physics Teachers, American Physical Society, American Association for the Advancement of Science.

Chemistry Education Research (CER) Based Capacity Building Programmes for Chemistry Teachers at UG Level

Savita Ladage

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Since its inception, the field of Chemistry Education Research (CER) has been addressing issues at the intersection of teaching and learning of chemistry at various levels of education. With primary aim to understand and improve chemistry learning, the work done in the CER field provides valuable insights to teachers, curriculum planners and policy makers engaged with chemistry education.

In Indian context, for chemistry teachers entering into the teaching profession at undergraduate (UG) level, it is not mandatory to have educational degrees like Bachelor or Master of Education. Thus, even though they are content experts, their exposure to pedagogical dimension and related areas is often limited. For innovation in classroom practices, assessment methods and development of instructional material, orientation of chemistry teachers teaching at UG level to research and development work in CER is required and will be useful. Thus, the Capacity Building Programmes (CBP) for chemistry teachers teaching at UG level needs to integrate dimensions such as teaching-learning challenges associated with chemistry as a discipline, key ideas associated with domains like chemistry lab education, problem solving and conceptual understanding in chemistry. It is important to critically reflect about such dimensions that can be included for CBP at UG level, as this is relatively less explored area in Indian context.

In the recent past, due to national efforts like Pandit Madan Mohan Malviya National Mission on Teachers and Teaching (PMMMNMTT), there is relatively more sensitisation about the pedagogical dimension among chemistry teacher community teaching at UG level. Various higher education institutions (e.g. IISERs) are venturing into CBP for chemistry teachers teaching at UG level. Additionally, the well-established global bodies associated with chemistry education like Royal Society of Chemistry (RSC) and American Chemical Society (ACS) are venturing in CBP and STEM education scenario in India. In addition to institutions like IISERs, IITs, academic autonomy is now also being granted to several state colleges affiliated to university systems. Thus, currently, the faculty members from diverse institutions have more freedom w.r.t. designing curricular content, its implementation and innovating the classroom assessment practices. The chemistry teacher community teaching at UG level in India today is more open and receptive towards innovations related to teaching-learning processes and associated aspects. Additionally, the National Education Policy (NEP) 2020 emphasises learner–centric approaches at UG level.

In this context, chemistry group at HBCSE has been conducting CBP with ideas derived from CER studies. The current talk, while reflecting on discipline specific challenges associated with chemistry, will also present our learnings based on the CBP experiences. These learnings give perspectives that can be useful for meaningful and required changes in existing curricula, assessment methods and teaching-learning practices in Indian context.

About the Speaker

Prof. Savita Ladage, has done her Masters in Analytical chemistry and Ph. D. in Chemistry Education. Her primary research interests are chemistry lab education at the undergraduate (UG) level and conceptual pitfalls in chemistry. She is involved with various chemistry education research and developmental activities, and programmes associated with the same. She closely interacts with chemistry teachers, especially those teaching at UG level, to orient them about research based innovative teaching-learning practices. Prof. Savita Ladage has chemistry/chemistry education related publications in peer reviewed national and international journals, pedagogical articles, book chapters and books. She is a member of the Editorial Advisory Board for Journal of Chemical Education (JCE), an ACS publication. She has also served as Co-opted member of International Steering Committee (ISC) for International Chemistry Olympiads (IChOs) on several occasions.

At HBCSE, she has been associated with two major impact programmes for more than two decades, namely, the Indian National Chemistry Olympiad (INChO) programme and the National Initiative on Undergraduate Science (NIUS) programme in chemistry. The former leads to selection of Indian teams for the IChOs whereas the latter conducts chemistry/chemistry education activities for motivated UG students and teachers teaching chemistry at UG level across India respectively.

For her contributions to the field of chemistry education, Prof. Savita Ladage was awarded the Nyholm Prize for Education by Royal Society of Chemistry (RSC), UK, in the year 2023.

Astronomy Education Research: Past, Present and Future Challenges

Urban Eriksson

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Discipline-based education research (DBER) takes the theories and methodologies of education research and applies them in the context of a specific discipline, in this example, astronomy. Research in the teaching and learning of astronomy has an extensive history; astronomy education research (AER), as its own separately defined field, is relatively new, stemming from the early to mid-1990s, as a separate track from physics education research (PER). By using a mixed-methods approach to textual analysis considering 2085 English language publications in the field, this paper paints a picture of the landscape of AER over the timespan of a century from 1898 to 2022. This paper finds that AER authors started regularly publishing around 1970 and took off significantly in the 1990s. AER, in its early era, was largely a USA endeavour dominated by ASTRO101. This has changed over time and in recent years, the USA has dropped below 50% of the worldwide AER publication production. It is found that “Celestial Motion”, “Instrumentation/Techniques”, and “Planetary Sciences (not Exoplanets)” are the most common content foci while a significant lack of local galactic and extragalactic education research is identified. Also, AER has been heavily focused on “Content Knowledge”, “Affective”, and “Engagement”. It is found that most articles tend to be general reporting of approaches or results rather than full empirical research, while there is very little theoretical or historical research in AER yet.

This overview provides a resource to researchers, educators, and other interested stakeholders allowing efficient ascertainment of previous research. This supports both researchers, allowing them to develop research questions at the cutting edge of the field, as well as practitioners, to inform their pragmatic approach based on latest research findings. I also present a set of recommendations and future outlook of the field of Astronomy Education Research.

About the Speaker

Urban Eriksson is a Full Professor at Uppsala University in Sweden. Uppsala University is the largest and oldest university in Sweden. He works at the department of Physics and Astronomy where he leads the research division on physics and astronomy education research. He is also deputy Head of department and Head of the Astronomy and fundamental physics unit. Prof. Eriksson is also instigator and chair of the biannual Astronomy Education Conferences (astroeducon.org) and instigator and Editor for the international Astronomy Education Journal (astroedjournal.org). He has been engaged in the IAU Commission

C1 as vice President and leader for the working group for Astronomy Education Research and Methods.

Prof. Eriksson has a background in physics and astronomy but also in teacher education and has spent 30+ years in educating students in all teacher-programmes about physics and astronomy. During this period, he turned to physics and astronomy education research (PAER) and got his PhD in 2014. After a Postdoc at Lund University, he developed his research and formed and led a PAER group at Lund University, Sweden, as associate professor, before getting the present position as full professor at Uppsala University, where he leads the research by the division, with colleagues, postdocs and PhD students. The division's four main focus areas are 1) Developing the theoretical framework for teaching and learning called Social Semiotics, 2) Investigating upper-division physics students reasoning and problem-solving skills, 3) Embodiment in physics and astronomy education and, 4) AI in teaching and learning in physics and astronomy.

Investigating Student Reasoning to Achieve Our Educational Goals

Vicente Talanquer

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In recent years, there have been numerous calls to reform science courses to address the needs and interests of diverse students and the societies in which they live. However, progress within educational institutions worldwide has been slow, and the impact of these reform efforts has often been limited. These calls highlight the need to reconceptualise learning objectives, instructional strategies, and assessment practices to ensure students develop the knowledge, higher-order thinking skills, attitudes, and values necessary to understand and responsibly address global challenges. To achieve these ambitious educational goals, we must examine the challenges students face in developing and applying the knowledge and reasoning skills we value. The findings from such investigations can provide valuable insights into the curricular, instructional, and assessment practices that best promote student learning. In this presentation, I will summarise findings from our research on student reasoning in chemistry, which highlight challenges in conceptualising and integrating central concepts and ideas in chemistry and applying them to analyse relevant problems. Additionally, I will discuss evidence-based educational strategies we have developed and implemented to enhance student understanding.

About the Speaker

Vicente Talanquer is a University Distinguished Professor in the Department of Chemistry and Biochemistry at the UA. His research focuses on undergraduate chemistry education. He has published over 150 peer reviewed and invited papers where he has explored the conceptual difficulties that students face when learning chemistry and the effect of different teaching strategies on student understanding. He has also investigated prospective science teachers' reasoning and practices. Dr. Talanquer has applied the results of his educational research to the development of innovative curricula for undergraduate chemistry education.

He has received various awards during his academic career, including the James Flack Norris Award for Outstanding Achievement in the Teaching of Chemistry by American Chemical Society, and the Educational Research Award by the Council of Scientific Society Presidents. In 2015, he was named Arizona Professor of the Year by the Carnegie Foundation. In 2019, Dr. Talanquer received the Education Research Award from the Council of Scientific Society Presidents, and he has recently been awarded the 2021 ACS Award for Achievement in Research for the Teaching & Learning of Chemistry.

From Einstein to Enigma with CCL

Manish Jain

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The biggest challenge we face today is student engagement. To address this, the Center for Creative Learning (CCL) at IIT Gandhinagar has dedicated the last eight years to transforming STEM education into a hands-on, engaging experience. We've created over 700 innovative models, games, and activities, reaching more than 5 lakh teachers across India, 6 lakh subscribers on Youtube/Instagram, 10 crore views and inspiring students to return to classrooms.

In this session, we'll explore the fascinating world of toys, machines, and games that reveal complex principles underlying everyday phenomena. We'll delve into the Enigma Machine, the stability of bicycles, and the 75 uniform polyhedra, uncovering the beauty and mystery in each. We'll also highlight notable moments in sports—like Neeraj Chopra's gold-winning javelin throw, PT Usha's near-bronze finish, and Jadeja's precise catch—demonstrating the interplay of mathematics and physics in our lives. Join us as we share our journey, showcase unique learning tools, and discuss the impact of experiential education on fostering curiosity and joy in learning.

About the Speaker

Manish Jain spends most of his time investigating the science behind simple (and complex) toys and is passionate about sharing his insights and excitement with people. He is an Associate Teaching Professor at IIT Gandhinagar, and heads CCL whose goal is to bring back the gleam in the eyes of students and children.

Before founding CCL, Manish worked at IUCAA's Science Centre in Pune, with Padma Shri Arvind Gupta. In his previous avatar, he spent 19 years in the area of chip design at Synopsys (Bangalore & Mountain View), serving as a Director of R&D.

Manish has a bachelor's degree in Electrical Engineering from IIT Kanpur (1993) and has also finished a few courses at Stanford University.

Advancing Biology Education in India: Integrating Innovation, Inquiry, and STEM Approaches for the Future

Samiksha Raut

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The future of biology education hinges on the integration of innovative teaching strategies, inquiry-based learning, and interdisciplinary STEM (Science, Technology, Engineering, and Mathematics) approaches. Key developments and milestones in biology education, highlights the shift from traditional lecture-based from traditional lecture-based instruction to more student-centered approaches such as active learning, course-based undergraduate research, experiential learning and the integration of digital tools. Several studies have demonstrated that these changes lead to improvements in student engagement, retention, and conceptual understanding. Additionally, interdisciplinary approaches, particularly the integration of biology with other STEM fields, have become more prominent, reflecting the interconnected nature of modern scientific challenges. In the light of these advancements, it is therefore, imperative to understand the role of professional development for educators, institutional curricular reforms, and the increasing use of data-driven strategies to meet the changing needs of the student population. Despite these advancements, challenges such as resource disparities, institutional barriers and the need for equitable access to quality education persist. This talk, therefore, focusses on ideas and strategies to help advance and contribute to the growing field of biology education by leveraging on India's National Education Policy, 2020.

About the Speaker

Dr. Sami Raut is an Associate Professor of biology at the University of Alabama at Birmingham (UAB). In the past, she has served as an Interim Assistant Dean of Academic Affairs at the Graduate School and Global Affairs and currently serves as a director of joint degree program – Genetics and Genomics with the School of Medicine and College of Arts and Sciences. She holds a PhD in Environmental Toxicology from UAB. She has taught majors and non-majors' students for nearly 15 years. After embracing realms of scientific teaching, she immersed herself in several biology education research projects. This led to mentoring of nearly 40 undergraduate students and several master's students at UAB. She has won several awards for her teaching and mentoring endeavors. Her primary area of research includes enhancing science literacy in societal topics of interest including climate change, sustainability, evolution, and vaccine hesitancy.

From Low-Cost Experiments to High-Tech Applications: Highlights of German Chemistry Education Research on Curriculum Innovation

Amitabh Banerji

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We have been working for more than 10 years on the implementation of future technologies into the curriculums of high-schools and universities. In 2017, we organised together with the TIFR and HBCSE a three-day hand-on workshop on Organic Electronics (Image 1). This was realised with our fully equipped material-kit, which allows you to build OLED and OPV devices without any clean-room facilities or expensive vacuum-techniques (Banerji, 2017). For more information on our material-kit "boxperiment OPE", please visit our website: http://www.boxperiment.de [2]. In my experimental-lecture on the epiSTEME10-conference, I will present two new topics from our current research programme.

Image 1: Three-day hand-on workshop on Organic Electronics, 2017

Low-cost hydrogen technologies
In the first part of my talk, I will introduce you to our new boxperiment Hydrogen [3]. In this unique approach we use small TicTac-boxes, which we functionalise as low-cost cells for water-electrolysis and hydrogen fuel-cells (Meggyes & Banerji, 2023; Banerji-Lab Website).

Teaching computer science in chemistry classes
In the second part of my talk, I will focus on a titration-robot, which can automatically conduct an acid-base-titration. For this, we use the LEGO Spike system, which allows to introduce computer science in chemistry classes without the need of textual programming.

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About the Speaker

Amitabh Banerji grew up in Berlin. He studied chemistry and computer science for teaching at grammar schools and completed his legal clerkship at the Herder-Gymnasium in Berlin Charlottenburg. From 2009 to 2012 he received his doctorate in the working group of Prof. Michael Tausch at the University of Wuppertal on the experimental-didactic indexing of organic light-emitting diodes. He then worked for two years as a lecturer and specialist coordinator at the Junior University of Wuppertal. In 2014 he joined as an Assistant Professor for chemistry education at the University of Cologne. Since 2019, Banerji has been a University Professor in Chemistry Education at the University of Potsdam where his research focuses on Curriculum Innovation & Research-Based-Implementation and Digital Tools in Science Education in Chemistry.

He has won several awards including the "Highly Commended" Project (OLEDs) at the European Science on Stage Festival, Debrecen (Hungary) and Brandenburger Innovationspreis Cluster Kunststoffe & Chemie 2021 awarded by the Minister of Commerce and Energy in Brandenburg for the project boXperiment.

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Strand 1

STEM Workforce Development

Classroom/Laboratory interaction and discourse

Assessment and evaluation

Professional practice and development of teachers

Educational initiatives and innovations

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Exploration of Chloroplast Localisation in Plant Anatomy Through Hands-On Microscopy Sessions with Secondary Students

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Hands-on learning strategies lead to enhanced memory, cognition, and improved problem-solving skills while connecting learners to real-world applications. Incorporating experiential learning into the curriculum, can significantly improve educational outcomes and better prepare students for future challenges. This study explores the localisation of chloroplasts in plant anatomy through hands-on microscopy sessions conducted with 83 secondary students. The aim is to enhance students' understanding of plant biology and microscopy skills by engaging them in practical observation. The study involves microscopy training, observation activities, and assessment, providing insights into the effectiveness of experiential learning in science education. Students were able to identify chloroplasts in various plant parts, noting their higher concentration in leaves and green tissues. Observing chloroplasts, which house the pigment chlorophyll essential for photosynthesis, solidified their understanding of the relationship between chloroplasts and chlorophyll and their roles in plant growth. The findings underscore the value of integrating hands-on microscopy sessions into the regular science curriculum to enhance technical skills and conceptual understanding in biological sciences.

Keywords: Chloroplast, Plant Anatomy, Microscopy, Hands-On Learning

Introduction

Microscopists like Leeuwenhoek and Hooke used microscopes to enlarge structures to understand their intricate details and functions, thereby laying the groundwork for modern cellular biology and microbiology (Ford, 1989). Despite the advancements, it has been observed that schools find it challenging to provide adequate laboratory experiences due to resource constraints (Kulshreshtha et al., 2022). Even at Grade 6 level, the Central Board of Secondary Education (CBSE) Science textbook introduces the complex phenomenon of photosynthesis. However, it seems semantically dense to comprehend the sentences and concepts. The use of hands-on and visual approach can be more comprehensive (Llewellyn & Frame, 2012; Markant et al., 2016). Kolb's Experiential Learning Theory suggests that learners build understanding through a cycle, this involves concrete experience, reflective observation, abstract conceptualisation, and active experimentation (Kolb et al., 2014). By providing students a space to directly observe stomata on different plant parts and to observe the process of osmosis in plant cells, microscopy offers a combination of hands-on and visual learning experiences. This study aims to enhance secondary students' (grade 6) understanding of chloroplast localisation and its role in plants by conducting hands-on microscopy sessions. In this process it will also improve students' technical skills in microscopy.

Theoretical Framework

Grounded in the theories of John Dewey, Piaget, Lewin and David Kolb, experiential learning emphasises the importance of learning through transformation of experience. Kolb's Experiential Learning Theory suggests that learners build understanding through a cycle, this involves concrete experience, reflective observation, abstract conceptualisation, and active experimentation (Kolb et al., 2014). This aligns with Piaget's Constructivist Theory, where students develop knowledge through doing (Kaur, 2023). In the case of biology, observing chloroplasts and similar cells/tissues through microscopes provides an opportunity of active learning that fosters deep conceptual understanding. Hands-on experiences enable students to bridge theoretical gaps, including the role of chloroplasts in photosynthesis, with their practical observations, leading to greater retention and engagement (Llewellyn & Frame, 2012).

Theoretical Framework, Research and Research Questions, Original Aspects

Kolb's Experiential Learning Theory highlights the idea of learning by doing. It emphasises that knowledge is created through the transformation of experience, combining both concrete experiences and abstract conceptualisation. The model consists of four stages: Concrete Experience, Reflective Observation, Abstract Conceptualisation, and Active Experimentation. Learners cycle through these stages, allowing them to integrate theory with practice. This theory explains the importance of hands-on learning (Kolb et al., 2014).

Research Questions

The study aims to address the following research questions:

- How can experiential learning strategies improve students' microscopy skills?
- How does chloroplast localisation enhance students' understanding of its role in photosynthesis?
- What is the impact of experiential learning on students' retention of biological concepts?

Methodology

83 Grade 6 students from Maharashtra were selected using purposive sampling, based on their performance in nationwide tests. Students were introduced to microscopy through a hands-on session. Various plant parts were examined for chloroplast localisation. Over an hour session, students observed findings on the distribution of chloroplasts across different tissues. Worksheets were provided to assess their understanding, which included questions on chloroplast location in plants and connection of chloroplast with photosynthesis. The worksheets were qualitatively analysed to evaluate student's comprehension of chloroplasts in different plant parts.

Findings

Students observed chloroplasts in various green tissues, gaining an understanding of the relationship between chloroplasts, chlorophyll, and photosynthesis. Initially, only 20 out of 83 students believed that green parts of fruits perform photosynthesis. However, after the hands-on session, they located chloroplasts in leaves, stems, and unripe (green) fruits, reinforcing the concept that photosynthesis occurs in multiple green plant parts, not just leaves. By the end of the session, they were able to locate chloroplasts in multiple green tissues and link this to photosynthetic activity.

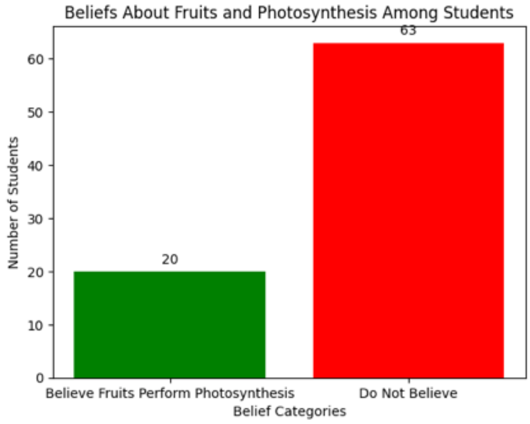

Fig. 1. Students' beliefs about photosynthesis and fruits.

Conclusion

Hands-on and visual approach significantly enhances students' understanding of chloroplast localisation and photosynthesis. By allowing students to directly observe plant structures, this method deepens their conceptual knowledge and improves their technical skills. We recommend incorporating such experiential learning strategies in science curricula to foster a deeper, more practical understanding of complex abstract biological concepts.

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Stars Over the Hills: Enhancing Rural Students' Interest in Physics Through Astronomy Outreach

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This study investigates the impact of an outreach program aimed at fostering scientific curiosity among rural students in Uttarakhand by integrating general astronomy into physics education. This initiative targeted schools in remote areas, using the allure of celestial phenomena to make physics concepts more accessible and engaging. The program included interactive astronomy workshops, observational activities, and hands-on experiments that connected physics principles with real-world astronomical events. To assess the program's effectiveness, a comprehensive evaluation was conducted, including pre- and post-program surveys, student interviews, and academic performance analysis. Results indicated a significant increase in students' interest in physics and a deeper appreciation for scientific inquiry. The program successfully enhanced students' understanding of physics by contextualising it within the fascinating realm of astronomy, thereby promoting a sustained interest in science and inspiring future academic and career pursuits. This study underscores the potential of using astronomy as a catalyst for broader scientific engagement in rural educational settings and effectiveness of targeted outreach efforts in bridging educational gaps and promoting STEM engagement geographically and economically underprivileged regions of Uttarakhand

Key words: Astronomy Outreach, Physics Education, STEM Education

Introduction

Rural school students in Uttarakhand often face significant challenges in pursuing physics as a subject in their future studies. The limited access to well-equipped laboratories and a lack of awareness about the real-world applicability of physics contribute to this reluctance. This disparity not only hampers their academic growth but also restricts their ability to explore career opportunities in science, technology, engineering, and mathematics (STEM) fields. To address these challenges, this study investigates the impact of an innovative outreach program that integrates general astronomy into physics education. By leveraging the natural curiosity that celestial phenomena inspire, the program aimed to make physics concepts more engaging and relatable. The intervention targeted Class 12 students from five rural schools in Uttarakhand, involving a total of 75 participants. The program sought to bridge educational gaps by contextualising physics learning within the framework of astronomy. Astronomy, with its visual appeal and intuitive concepts, serves as an ideal medium to demonstrate the real-world applicability of physics. This approach not only aimed to foster interest in physics but also to empower students with the critical thinking skills and scientific curiosity necessary for better academic performance and career decision-making.

Theoretical Framework

The program was grounded in constructivist learning theories, emphasising hands-on, experiential education to connect theoretical knowledge with real-world phenomena. Astronomy, with its visual and intuitive appeal, served as a framework to enhance students' conceptual understanding of physics, while promoting critical thinking and scientific inquiry. The intervention aligns with the National Education Policy (NEP) 2020's goals of fostering STEM education through innovative and contextualised teaching strategies.

Research and Original Aspects

This research focuses on the effectiveness of astronomy-based physics education as a tool to address educational challenges in geographically and economically disadvantaged regions. The unique aspect of this study lies in its integration of observational activities, interactive workshops, and experiments that bring together theoretical physics and practical astronomy. It highlights the role of targeted outreach programs in bridging educational gaps in rural areas.

Research Questions

- How does integrating astronomy into physics education impact students' interest in physics and scientific inquiry?
- Can contextualising physics concepts through astronomy improve students' academic performance?
- What is the long-term impact of such an outreach program on students' academic and career choices in STEM fields?

Methodology

The study was conducted in five rural schools in Uttarakhand with a sample of 75 students of Class 12. The program consisted of:

- Interactive Astronomy Workshops: Covering basic celestial phenomena and their physical principles.
- Observational Activities: Night sky observations using telescopes to connect theoretical concepts with real-world phenomena.
- Hands-On Experiments: Practical experiments linking physics concepts to observable astronomical events.

In this study the data collection methods included pre- and post-program surveys, student interviews, and academic performance evaluations. Follow-up surveys tracked students' academic and career choices post-intervention.

Findings

The program demonstrated a significant positive impact on students' interest and engagement in physics:

- **Academic Pursuits**: Of the 75 students, 40 chose to pursue physics at the undergraduate level, 20 enrolled in diploma courses related to physics, and 15 opted for other fields.

- **Interest in STEM:** Students showed a deeper appreciation for scientific inquiry and critical thinking.
- **Conceptual Understanding:** Observational activities and experiments contextualised physics principles, making them more relatable and easier to grasp.

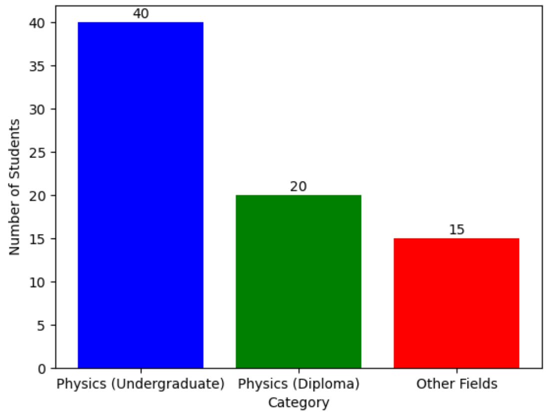

Fig.1. Academic pursuits of Students after conducting outreach programme

Conclusion

The current study underscores the transformative potential of using astronomy as a catalyst for broader scientific engagement in rural educational settings. It highlights the effectiveness of targeted outreach programs in bridging educational gaps and promoting STEM education among school students of rural community. Through integrating basic astronomy concepts into physics education, the initiative not only enhanced students' academic performance but also inspired them to pursue science-related academic and career paths, thus contributing to a more inclusive STEM ecosystem in Uttarakhand.

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Roles Played by Students' Prior Knowledge in Classroom Discussions

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Classrooms are spaces which demand communication. In every classroom, exchange and construction of knowledge takes place. In most classrooms a bulk of communication is done by the facilitator but students also participate in the classroom communication. There are a lot of factors on which the participation of students in the classroom depends on; like their personalities, language of classroom interaction, the facilitators' beliefs, and students' prior knowledge. In this paper, we will be looking at instances where students' prior knowledge helped them participate in the classroom interaction.

Keywords: Classroom Discourse, Prior Knowledge, Classroom Interactions

Introduction

A lot has been said about how knowledge is constructed in a classroom in a participatory way. In a lot of classrooms, the facilitator might be looked upon as an authority who determines the classroom discourse but a lot of times students' participation can change this discourse. Students raise queries, or respond to inquiries (Abdullah, et al., 2012). The participation of students depends on many factors such as the facilitator's beliefs, language of instruction, cultural background and environment. Another important factor which can affect students' active communication in the classroom interaction is their prior knowledge. Prior knowledge is the knowledge or information that is already known to students. This knowledge or information can come from many activities done by them, their other experiences and observations (Ahied et al., 2020). Students make connections between what they are learning and what they already know by using their preexisting knowledge, ideas, and understanding to interpret new information (Ambrose, et al., 2010). Prior knowledge can stimulate interest, guide attention, help interpret new information, aid memory encoding, enable logical inference, and guide problem-solving (Ormrod, 2019). The prior knowledge that the students bring to the classroom can be accurate but not relevant for the current topic or can be inaccurate or can be incomplete (Diaz, 2017)), this inaccurate knowledge can form misconceptions (David, 2017) and sometimes also hinder future development (Ambrose, et al., 2010).

Research Questions

The study aims to address the following research questions:

- How does students' prior knowledge encourage their participation in the classroom?
- Does the choice of topics affect students' classroom participation? How is this related to their prior knowledge?

Methodology

The focus of study was to understand how students' prior knowledge influences their participation in the classroom interaction. Here by prior knowledge, we mean knowledge that students gain from their experiences and observations outside the classroom or bringing from their everyday contexts. Two different sessions covering secondary level topics with the same set of 26 students were observed. Each session was 150 minutes long. Observation notes written down during the sessions were used as data to get an idea of the overall session. Even though the session was fully video recorded, only some parts of the videos from both the sessions were used as data for this study. The selection of video clips was based on the observation notes. The purpose of watching videos was to identify the conversation between students and facilitators where prior knowledge was used. After multiple times of watching the videos, the conversations were transcribed and analysis was majorly done based on that transcript. But, video clips provided additional information about gestures, body languages and the nature of interaction among individuals.

Findings

In one of the conversations analysed, one would see students discuss whether pickles can get spoiled or not. Students were trying to give statements to support their view regarding whether pickles were spoiled or not spoiled. Even though the ingredients of a pickle and their connection to a pickle getting spoiled or not had not been discussed, one student commented on the ingredients of pickle and their preservative nature. The student also commented about 'preservation' and 'preservatives' two terms which were not mentioned in the class till then, in order to add strength to the reasoning and concluded that the pickle was not spoilt. 'Finding the conditions of spoilage' was not a part of the session but the student listed the conditions in which pickles can undergo '*spoilage*'. The student's prior knowledge about pickles and their preservative nature might have helped the student guess the objective of the session and further helped the student in making a conclusive statement about pickle getting spoiled or not. In another session on Soil, while a discussion about laterite soil was going on, the students were asked to think about other types of soils which exhibit similar properties as the laterite soil. One of the students cited cement as an example because it becomes hard when it dries up. But some students objected to it and said it was not purely soil but a mixture of soil and other components. Here one can see two kinds of prior knowledge helping in the classroom discussions. And both of them together helped in building a conversation and helped in learning. Another student could build a connection to the conversation going on in the classroom to the houses she has seen during the visits to her native village (Goa). Excitement of being able to see something she had seen earlier to the classroom was evident from her gestures. This instance can be seen as an example of students' feeling confident while she builds a connection between classroom topics to her own experiences. This finding is consistent with the findings from other studies (Geoffrey, 2021), that precise prior knowledge instills confidence in learners during the teaching and learning process. Students who have 'sufficient' prior knowledge are able to make connections between the new knowledge and their existing experiences, which allows them to actively engage in the teaching and learning process. It can increase their self-esteem and confidence. (Stenlund, 2010)

Conclusion

Classroom interaction is a conversation between the facilitator and the students and also among the students themselves. Activities involving commonly seen resources like food or soil enable the students to share their prior knowledge in the classroom hence enhancing the quality of classroom interactions the students have. Topics like food and soil can give facilitators and students opportunities to build new knowledge along with enhancing or correcting their prior knowledge. The facilitator should search for topics and opportunities which will enable students to use or correct their prior knowledge, and use their experiences in the classroom. In our analysis, we observed instances where a student's prior knowledge helped the facilitator move the classroom discourse towards the objective of the session. We also saw an example of how inaccurate prior knowledge led to an interaction between students. Lastly, we also found examples where prior knowledge helped an individual student feel confident and relevant in the classroom. Research points out all these as effects of students' prior knowledge on classroom interactions. We conclude that these instances show us that every piece of prior knowledge that students get to the classroom can be valuable, and can be considered as a foundation for building further knowledge or correcting earlier knowledge.

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Inception and Development of Astronomy Lab at Vikram A Sarabhai Community Science Centre

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Astronomy Lab at Vikram A Sarabhai Community Science Centre (VASCSC), Ahmedabad was started in 2020. Here we will explore the ways how we have set up the Astronomy Lab, its various programs, the challenges and insights from implementing them to diverse students. The hands-on activities, publications, outreach and in-reach programs for students and teachers in line with National Education Policy (NEP) 2020 developed by our team will be discussed. We reached around 3000 students and around 200 teachers from 2021 to 2023 through "Astronomy Workshops" in Gujarat. Different in-reach programs catered to almost 4000 middle and high school students over the years. Apart from this our team also participated in various rural and urban teacher trainings across the country carried out by the centre. We will share the learnings from these programs and present this as a case study for improvements in astronomy education, making it more inclusive in a developing and diverse country like India.

Keywords: Astronomy Education, Hands-on activities, Outreach, Experiential Learning, Bagless Learnings

Introduction

The Astronomy Lab at VASCSC, Ahmedabad began in 2020 just before COVID-19. This presentation outlines the setup of the lab and shares challenges and insights from its setup and implementation of various programs.

Original Aspects

Our team has developed hands-on activities, publications, and modules for outreach and in-reach in astronomy, tailored to the National Education Policy (NEP) 2020. These meticulously selected topics connect astronomy with daily life, extending non-formal and hands-on learning to informal learning through unaided celestial observations.

Methodology

We conducted a major outreach program, "Astronomy Workshops," in underprivileged schools across Gujarat from 2021 to 2024, reaching about 3000 students and 200 teachers. Our in-reach programs served nearly 4000 middle and high school students. Our team also carried out national and state-level training sessions in notable programs for students and teachers organised by the centre.

Methods and Findings

This section shares challenges and insights from in-reach and outreach programs at urban and rural levels. It covers module development and grassroots implementation. We present this as a case study for improving astronomy education in a diverse and developing country like India. Success stories from different programs will also be highlighted.

Conclusion

The lessons from this grassroot program can aid astronomy and science educators. They can help design future activities, publications, and programs for urban, rural, and indigenous students. This effort supports the vision to make astronomy education as inclusive as possible.

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Embodied Pedagogy in Mathematics Teacher Preparation – Insights from Cases

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Embodied pedagogy in mathematics teacher education is a globally emerging field of practice and research. This paper reports on selected individual cases from an intervention, where mathematics teachers were introduced to the discourse and practice of embodied pedagogy. Drawing on individual journeys of selected participants, the paper traces learning trajectories and offers insights into the affordances of embodied pedagogy for mathematics teacher preparation. In India, where both policy and scholarship call for a revitalisation of mathematics education, embodied pedagogy has the potential to broaden the perspectives of mathematics teachers.

Keywords: Embodied Pedagogy, Mathematics Teacher Preparation, Middle School Geometry

Introduction

Embodied pedagogy in mathematics teacher preparation is an interdisciplinary area of research and practice. As a discourse and practice, embodied pedagogy foregrounds the tenet that cognition is grounded in the actions of the body (Donovan & Alibali, 2021: 136). While there is a significant amount of literature in the underlying fields of embodied pedagogy in mathematics education (Abrahamson, 2013; Nathan et al., 2014; Smith & Walkington, 2019) and embodied pedagogy in teacher education (Dixon & Senior, 2011; Estola & Elbaz-Luwisch, 2003; Hegna & Ørbæk, 2021; Klein et al., 2019), the scholarship on the intersection of these areas is limited. This paper traces the learning journeys of selected individual participants from a workshop conducted to introduce pre-service and early career mathematics teachers to the discourse and practice of embodied pedagogy. Through these individual cases, this paper argues that embodied pedagogy affords the opportunity and tools for mathematics teachers to arrive at a more nuanced understanding of the role of the body in learning; strengthen conceptual understanding; and contest prevailing assumptions about the nature of mathematics and how it should be taught.

Context and Method

This paper is based on a small-scale action research study conducted in 2023-24. As part of the study, a 30-hour intervention was designed and delivered to a cohort of 14 self-selected pre-service and early career mathematics teachers from across India. It draws on interviews, classroom episodes, and reflective group discussions to capture the experiences of selected participants across three areas of learning. The first area considers the participant's understating of embodied pedagogy by analysing their engagement with experience, specifically what Hegna and Orbaek (2021) refer to as 'cognitive experience'. The second area focuses on the participants' conceptual understanding of geometry. Finally, the third aspect focuses on the participants' understanding of mathematics pedagogy as a process of mathematisation as discussed by Subramaniam (2022).

Key Findings

Engaging in the intervention gave participants the tools and opportunities to recognise the interconnected nature of the mind and body and develop an appreciation of the role of the body in learning (Nguyen & Larson, 2015). For example, Savitha (name changed) said “So, here [in traditional classrooms] the understanding is creation of knowledge is seen as something that happens only through the mind, whereas in embodied pedagogy, it makes use of body like, say, through movement, action, gestures, etc., along with the mind as a way to understand and to create knowledge” (Day3_Savitha_check in).

A further finding that emerged is that the use of embodied pedagogy was able to highlight information that was otherwise hidden (Donovan & Alibali, 2021: 141) and thus strengthen the conceptual understating of the participants. This occurred when they were working with special cases of quadrilaterals using a length of ribbon which allowed for the shapes to be constructed and manipulated in different ways. Revathi comments “so earlier for me, those four were separate figures like, ‘this is square’, ‘this is rectangle’, ‘this is rhombus’, ‘this is parallelogram’. Though I was aware of their properties but just instantly establishing any relationship amongst those four figures was a little difficult for me. But as I was doing it with the help of ribbons and I was able to manipulate it. I think that’s what helped me clear my understanding, better my understanding” (Day 3_Revathi_Check in).

Embodied pedagogy enabled the participants to question the common assumption in mathematics pedagogy that there is one correct answer to a question and one correct method of arriving at that answer (Kumar et al., 2012: 158). Savitha commented “We think differently each one… So, our ideas of even something like congruency (can be different). Here when you have the freedom to move, your thoughts also flow accordingly… here when I'm playing around with a triangle … I see it's more natural like flowing with my thoughts than standardising everything and I think that's beautiful” (Day 5_Final Reflection). Embodied pedagogy foregrounds collective and collaborative learning and highlights the possibility of multiple ways of arriving at a mathematical conclusion. When this multiplicity is acknowledged, there is a possibility of seeing how the concept is itself co-created by the learners and the environment.

Conclusion

Policy documents (GoI, 2020; NCERT, 2005) and scholarly literature in India call for a revitalisation of mathematics education with a focus on mathematics teacher preparation (Ramanujam & Subramaniam, 2012). This revitalisation needs mathematics education to be less burdensome and to move towards mathematisation rather than algorithmically motivated rote learning. In chronically under-resourced educational contexts that exist in India, embodied pedagogy can offer mathematics teachers a more sustainable option. However, for embodied pedagogy to see more widespread acceptance, there needs to be a substantive shift in the perception of the body in learning.

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Unveiling the Nature of Science: Insights from School Students

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In India, unveiling the Nature of Science (NOS) is crucial, given the country's significant investments in STEM. This paper investigates Indian student's comprehension of the NOS and identifies the factors influencing their understanding. A purposive sampling method was used to select schools representing different regions, socioeconomic backgrounds, and types of educational institutions (public, private, urban, and rural). The sample included 374 students and 43 teachers from 15 schools of Samastipur, Bihar. Through a critical analysis of current literature and empirical research, this study aims to provide insights into the current state of science education in India and suggest ways to enhance student's grasp of the NOS.

Keywords: Nature of Science, Empirical Nature of Science, Tentative Nature of Science, Subjective Nature of Science, Socio and Cultural Embeddedness of Science, Science Education, School, Curriculum

Introduction

Science education is fundamental to fostering a scientifically literate society. The Nature of Science (NOS) encompasses the epistemological foundations of science, including the processes by which scientific knowledge is developed, validated and refined. In India, where science and technology are seen as drivers of national development, a robust understanding of the NOS is essential for students. However, research suggests that students often have misconceptions about scientific processes and the nature of scientific knowledge, which can hinder their ability to engage with science meaningfully.

Problem Statement

Despite the importance of the NOS, many Indian students demonstrate a limited understanding of its key principles. This gap in understanding can be attributed to various factors, including curriculum design, teaching practices and assessment methods. The challenge lies in the disconnect between the intended outcomes of science education and the actual understanding students develop. This work seeks to explore these issues in depth, focusing on how the NOS is conveyed in Indian schools and the extent to which students internalise these concepts.

Literature Review

Key studies by Lederman (2007) and Driver et al. (1996) emphasise the importance of explicitly teaching NOS principles to students. In the Indian context, studies like those conducted by Natarajan (2014) and Kumar (2017) reveal that students often struggle with understanding the empirical and tentative Nature of Science. The "National Curriculum Framework (NCF) 2005, National Education Policy (NEP) 2020 and National Curriculum Framework for School Education (NCFSE) 2023" advocates for a more inquiry-based approach to science education, emphasising the need for students to develop a nuanced understanding of the NOS. However, implementation challenges persist, as noted by research from the Azim Premji Foundation (2019), which highlights the prevalence of rote learning and insufficient teacher training in effectively conveying NOS concepts.

Theoretical Framework

The theoretical framework for this study is grounded in constructivist theories of learning, which suggest that students construct knowledge through experiences and interactions. According to Piaget and Vygotsky, meaningful learning occurs when students actively engage with content, allowing them to build on prior knowledge. The Nature of Science, as part of this framework, should be taught not as a set of facts but as a dynamic process that students can relate to their everyday experiences. The various key concepts of NOS include empirical and tentative nature, subjective and creativity and socio-cultural embeddedness of science.

Research Questions

- How do school students understand the Nature of Science?
- What factors influence student's understanding of NOS in schools?
- How effectively are NOS concepts integrated into the Indian science curriculum?
- Is there any gender-based differences in students' understanding of the Nature of Science (NOS), and what factors might contribute to these differences in comprehension and engagement with science concepts?

Original Aspects of the Study

This study contributes to the existing literature by:

- *Focusing on the Indian context:* While much research has been done globally on NOS, there is a need for localised studies that consider the unique challenges and opportunities in Indian education.
- *Comprehensive analysis:* The study combines a literature review with empirical research, providing a holistic view of the issues at hand.
- *Policy implications:* The findings of present study have direct implications for curriculum designers, educators, and policymakers in India.
- Gender-based differences: In the students' understanding of the Nature of Science (NOS) is there any role of gender, and to explore potential factors that may contribute to these differences.

Methodology

This study adopts a qualitative research method to gain a comprehensive understanding of the issues. Schools were chosen using a purposive sampling method to ensure diversity in geography, socioeconomic status, and school type (public, private, urban, and rural). The sample consisted of 374 students and 43 teachers from 15 schools in Samastipur, Bihar. The data were obtained using the VNOS-C tool, which was administered to students of various ages and educational levels in several schools, as well as semi-structured interviews with science teachers. Curriculum materials, textbooks, and assessment papers were examined to determine the representation of NOS concepts in the Indian educational system. The qualitative data from the questionnaire and Interview were analysed with help of the given rubrics of the tool, thematically to identify common theme and challenges related to NOS.

Findings

Student's Understanding of NOS

The survey results indicated that a significant proportion of students view scientific knowledge as absolute and fail to recognise its tentative nature. Additionally, many students struggled to differentiate between observation and inference, leading to misconceptions about the empirical basis of science. The role of creativity and subjectivity in science was poorly understood.

Factors Influencing NOS Understanding

The study identified several factors influencing student's understanding of NOS:

- *Curriculum Gaps:* While the NCF 2005 emphasises inquiry- based learning, many textbooks lack a clear focus on NOS principles.
- *Teaching Practices:* The dominance of lecture-based teaching methods, coupled with a lack of hands-on experiments and discussions, limits student's engagements with NOS concepts.
- *Assessment Methods:* Standardised exams prioritise factual recall over conceptual understanding, discouraging students from critically engaging with NOS.
- *Teacher Training:* Many teachers expressed a lack of confidence in teaching NOS, citing insufficient training and resources.
- *Gender:* Gender-based differences in NOS understanding in Indian schools may be influenced by a combination of confidence levels, engagement, teacher interactions, access to resources, and societal expectations. Addressing these disparities may require targeted interventions to encourage female students' engagement in hands-on science activities and reduce the impact of gender stereotypes in science education.

Conclusion

Unveiling the Nature of Science is crucial for students to become informed, critical thinkers capable of engaging with scientific issues in their everyday lives. Addressing these challenges requires a concerted effort from educators, policymakers, and curriculum developers. The study's findings reveal significant gender-based disparities in students' understanding of the NOS in Indian schools. Female students often showed a nuanced understanding of NOS. Conversely, male students reported higher confidence, often benefitting from greater access to science resources and encouragement in practical science applications. By fostering a deeper understanding of NOS among students, India can cultivate a generation of scientifically literate citizens who are well-equipped to contribute to the nation's development.

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Reflective Practices in Science Teaching: A Way to Transform Child's Experience into Learning

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One important strategy for bridging the gap between a child's everyday experiences and formal learning is to use reflective practices in scientific education. The present study investigates how reflective teaching approaches can improve science instruction by stressing on the value of creating a classroom atmosphere that stimulates students' interest, critical thinking, and sense of personal connection to scientific ideas. Reflective teaching practice is going back to his\her own method of classroom instruction by a teacher and reformulating the same according to the need of a child in a science classroom. Further it can be significant tool for Professional Development of teachers.

Keywords: Reflective Teaching Practice, Science Classroom, Professional Development of Teachers, Critical Thinking

Introduction

Teachers who engage in reflective practice gather evidence about their teaching practices with the goal of analysing, interpreting, and evaluating their experiences in order to improve their future instruction (Mathew & Peechattu, 2017; Farrell, 2016). This type of inquiry is cyclical and systematic. Additionally, it is a process of creating meaning that helps educators advance (Rodgers, 2002). Reflective educators strive to better understand themselves and often relate to other ideas.

Problem Statement

The general method of teaching science frequently emphasises rote memorisation which hinders students' ability to develop critical thinking and problem-solving abilities. There are extra difficulties due to limited resources, insufficient teacher preparation, and contextual variations. This gap can be filled in part by using reflective practices in science education, wherein educators carefully consider both their own pedagogical approaches and students' educational experiences.

Review of Related Literature

Enhancing teacher quality is another benefit of reflective practice. Professional development, which is commonly defined as how a teacher acquires specific information and a set of abilities within a given context of scenario, is one component of teacher quality that is impacted by reflective practice (Koellner & Jacobs, 2015). Teachers can unlearn inefficient teaching strategies that could negatively impact students' learning experiences by reflecting on their own practices, which raises their awareness of what they are doing (Ciampa & Gallagher, 2015). According to Meierdirk (2017), pre-service teachers typically employ reflection to enhance their instruction in the areas of behavioural management, lesson planning, activities in the classroom, and performance indicators. Alger (2006) provides an illustration of the influence reflective practice has on pre-service teachers.

Research Questions

- How do science teachers currently engage in reflective practices in their teaching methods, particularly in rural schools?
- What are the perceptions of science teachers regarding the importance and impact of reflective practices on students' learning experiences?
- How can reflective practices be effectively integrated into science teaching to enhance students' engagement and understanding of scientific concepts?
- What specific reflective strategies do science teachers find most effective in transforming students' real-life experiences into meaningful learning in science education?

Methods

Qualitative Methods (Document analysis and research papers) will be used to support the in-depth analysis of the present research and finding will be analysed on the basis of research questions and problem of statement.

Conclusion

In conclusion we can assert that reflective practices in science teaching are not merely a pedagogical tool but a transformative approach that can significantly enhance students' learning experiences. By fostering a deeper connection between science education and students' everyday lives, reflective practices help cultivate a generation of learners who are not only knowledgeable but also curious, critical, and equipped to navigate the complexities of the world. As we move forward, it is imperative to recognise the value of reflection in teaching and to integrate it into the fabric of science education to ensure that every child's experience is transformed into meaningful, lifelong learning.

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Differing Approach in Design of Teaching Learning Material on Soil for Students with Different Backgrounds

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This paper presents a comparison of resources developed on the same theme, 'Soil', as a part of two different projects/studies namely, *Vigyan Pratibha (VP)* and *Culturally Responsive Science Teaching (CReST)* catering to audiences with distinct backgrounds. VP reaches students from mostly urban backgrounds while CReST to students from remote tribal regions. In this we discuss the distinction in student's day-to-day experiences based on their socio-cultural background and rationale behind the design of the resource materials developed. Also emphasizing on the need for contextualising classroom discourse based on students' cultural capital, making even the science classrooms relevant and responsive.

Keywords: Comparative Study, Local Context, Responsive Approach

Introduction

Soil is present everywhere on earth, but there can be significant differences in the experiences the students have with soil, based on their background. In this paper we will discuss the tales of two modules developed on the same topic, 'Soil', as a part of different projects/studies, one catering to a broad group of students (spanning urban and rural backgrounds) while other catering to students from remote tribal regions. It will highlight the differences in the students' experiences and bring out the contrasts in the approach in module designing.

Sampling, Research Method and Data Collection

For this study we consider two projects which cater to students from different socio-cultural background;

A. The Vigyan Pratibha (VP) project was introduced for secondary school students, to nurture their talent in science and mathematics (Gupta A., 2018). Many of the schools involved cater to students from urban backgrounds who might not have direct experience with soil. Even some of the rural school students today are found to have very little experience of playing/working with soil.

B. Culturally responsive science teaching (CReST) studies carried out with the aim to bridge the divide between students' day-to-day experience and the classroom discourse for secondary class. Here we focussed on students from tribal regions who are well connected to nature (Redij A. et al., n.d.). They have a close connection with soil.

The data for VP included observation notes and students' written responses of VP Learning Unit, from two Kendriya Vidyalaya schools in Mumbai and Mumbai Suburbs. The data for

CReST included observation notes taken during the school visits to understand the student's culture and audio recordings of student interaction during classroom trials of the module in two tribal schools in Gadchiroli district. Comparative studies carried out with a Socio-constructivistic worldview using qualitative analysis methods.

Findings

Comparing students' connect to 'soil'

The students reached by two projects showed different engagement with soil based on their socio-cultural background. Differences from students' responses are highlighted in Table 1.

VP (Urban) students	CReST (tribal) students
1. Students' connection with soil was limited to playing outdoor games such as cricket, kabaddi and football. 2. Known use of soil was chuna for painting walls, and geru for rangoli. 3. The majority of them are not familiar with soil related activities such as farming, gardening and construction. 4. Colours of soils seen are red, black and grey.	1. Soil is used to make articles, toys and equipment to catch birds. 2. Soil used to plaster mud walls and painting. 3. Use of soil for medicinal purposes. 4. Most of them have close familiarity with farming and some in brick making. 5. Colours of soil seen are red, yellow, white, black and gray.

Table1. Table below list the responses related to student's connection with soil collected through students' responses and fieldnotes from classroom observations.

Reviewing design of the modules for different audience

The students from tribal regions have direct engagement with activities related to soil while for other group it's tertiary mostly through books or media. The design, approach and learning outcome of the modules differ based on the student's background as highlighted in Table 2.

Project: Module	VP: No soil, no us; know soil, know us!	CReST: Soil, plant and us
Aim	Explore diversity of soil in locality, its physical and chemical properties, and usage through observation, tests, classroom discussion and interaction with elders.	To detect the presence of iron in soil and its transfer to plants and humans (elemental cycle) through activities such as observation, thinking, discussions, hands on experiments, role play etc.
Approach	1. Deficit-based approach providing missing experiences, using open ended questions for students to think about the use and properties of soil	1. Asset-based approach integrating prior knowledge. Connecting the daily life experience of soil with the classroom curriculum.

	and routes for re- construction of soil. 2. Tasks developed to recognise the importance of discoveries for social and economic reasons.	2. Learning process of scientific inquiry by comparing iron in soil samples with blank test and control samples.
Learning Outcome	Cover multiple properties of soil giving exposure to the missing experiences related to soil. Learning through inquiry and discussion, less details of underlying chemistry (to limit the module length and to maintain consistency with national curricula).	Discussing the funds of knowledge students possess. Focus on the theme of transfer of micronutrients at different biotic levels and their role at each level. Underlying chemistry is taught explicitly.

Table 2. Highlights of the similarities and differences in aim, approach, outcome of the two modules on soil.

Conclusion

The design of the modules took cognisance of the students' background and their experiential capital. For urban students it acts as a scaffold to give them the missing experience, building their connection to nature. For students from tribal regions with close connection to nature and thus the soil, it serves to connect their experiences to the classroom discourse and appreciate its relevance in their day-to-day life.

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Understanding Different Facets of Atal Tinkering Laboratory: A Preliminary Study

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Atal Tinkering Laboratory (ATL) claims to provide a unique platform for young learners to explore, innovate, and develop solutions to real-world challenges. To fully realise the potential of such labs, a closer look at their implementation in schools and achievement of intended objectives is necessary. To this end, this study aims to explore the experiences and teaching-learning processes of ATL in a private school. Using semi-structured interviews and classroom observations, we gathered insights from different stakeholders, examining various aspects such as infrastructure, resources, course structure, pedagogy, assessment, learning outcomes, teacher training and support, motivation, challenges, and future aspirations.

Keywords: Atal Tinkering Laboratory, Experiences, Teaching-Learning Processes

Introduction

The concept of maker spaces in educational settings has gained significant attention in recent years. Similarly, Atal Tinkering Laboratories (ATLs) are established with an intent to offer learners a dedicated workspace where they can freely explore, ideate, and create solutions to real-world problems from a young age (National Institute of Transforming India Aayog, 2021). The primary objective of ATL is to foster a DIY (do-it-yourself) culture and develop innovative and entrepreneurial skills, while deepening their understanding of STEM fundamentals.

Despite the potential of such lab, it is essential to examine how they operate within school settings and whether they are meeting their intended goals. Some studies have been conducted in the last few years which have tried to understand the awareness of different stakeholders regarding ATL (Kavya & Rishinath, 2019), and how effectively it is implemented in school settings (Pathak & Mane, 2022). As ATL is still in its initial stage, limited research has been conducted on this initiative. To fully comprehend how such lab functions within schools, a comprehensive analysis of various aspects, including curriculum integration, classroom dynamics, stakeholder experiences, and more, is necessary. To this end, this study aims to explore the perceptions, experiences, and teaching-learning processes of ATL. We have tried to look into various aspects including the infrastructure, resources, course structure, pedagogy, assessment, learning outcomes, teacher training and support, motivation, challenges, and future aspirations.

Methodology

This study was conducted at a private school, Dayanand Anglo-Vedic (DAV), in East Delhi. The participants included the principal, the lab in charge, and students (23). To gather information regarding infrastructure, a checklist was employed. To gain insight into the classroom environment, lesson transaction, activities conducted and student engagement, classroom observation was carried out. To understand stakeholders' perspective, semi-structured interviews were conducted. The data has been analysed using thematic analysis (Braun & Clarke, 2006, 2012). This comprehensive approach enabled us to gain a deeper understanding of the ATL's impact and dynamics within the school setting.

Findings and Conclusion

We found that in particular setup, the students' motivation to participate in ATL was largely driven by personal interest and teacher encouragement. Most of the students agreed that the resources are available and support them in learning. Participants have positive responses towards pedagogy followed and supportive learning materials. The experience seems similar to that of Fab Lab (Fabrication Laboratory) which closely aligns with DIY movement and maker culture. The researches on fab labs' impact on learning revealed consistent findings including enhanced learner interest and engagement, positive attitudes towards utilising such labs, and initial tool-handling difficulties followed by rapid adaptation (Rayna, & Striukova, 2021; Togou et al. 2020).

The overall experiences of the stakeholders in ATL, also revealed various areas which need improvement in terms of refining assessment methods, providing comprehensive career guidance, adequate funding, salary of in charges, frequent industrial exposures, coordinating calendar activities with term exams, and formalising programs to maximise the impact.

It is however important to note that the conclusions drawn from this research are specific to the participating school owing to the study's localised and small-scale design, and their broader applicability remains to be explored.

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Exploring Higher Education (HE) Teachers' Attempt to Multidisciplinary Curriculum Design

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NEP 2020 has stressed the introduction of a Multidisciplinary Curriculum also indicated by its appearance 70 times in the document. However, as a policy document, it is not scoped to thrash out the meaning or the way to implement it, leaving out a space for lack of intersubjective understanding. At the same time, providing opportunity to explore and understand varied perspectives. A series of three workshops were conducted with 85 undergraduate teachers from across Maharashtra to help design a multidisciplinary module. This article highlights the analysis of a multidisciplinary module design based on curriculum framework and graduate attributes criteria. The study suggests that the challenge seems to be in the seamless integration of various disciplinary ideas centred around a theme. The SOCME diagram is a helpful tool and there is a need to orient teachers in this direction.

Introduction

Traditionally, undergraduate students get domain-specific training. However, multidisciplinary curriculum implementation is becoming increasingly important as it improves cognitive, affective and critical thinking abilities (Aris et al., 2017). The ability to work with multidisciplinary team is being viewed as the need for 21st century undergraduate educational outcomes (Hardy et al., 2021). In India, there has been a wide range of conceptions about the definition of Multidisciplinary Curriculum since the introduction of NEP 2020. Some of these are as follows.

a) liberal arts,
b) subjects such as archaeology, architecture which is informed by multiple domains,
c) the choice-based credit system (CBCS) which offers choices to take multiple disciplines,
d) cluster universities/colleges with arts, science and commerce streams.

UNESCO (2013) defines multidisciplinary education as, "*An approach to curriculum integration which focuses primarily on the different disciplines and the diverse perspectives they bring to illustrate a topic, theme or issue. A multidisciplinary curriculum is one in which the same topic is studied from the viewpoint of more than one discipline*". (p.42)

Theoretical Framework

Novak's theory of meaningful learning includes the development of cognitive abilities, skills and the affective domain. Multidisciplinary thinking is a cognitive ability as well as a skill that needs to be developed at the undergraduate level to solve present-day real-life problems such as climate change, water scarcity etc. Even technological advancements such as space exploration need a multidisciplinary approach. Thus, it is important to inculcate multidisciplinary perspectives to solve a real-life problem (Golding, 2009). However, there is no prescriptive syllabus available for teachers to impart these ideas. Workshops were organized to facilitate HE teachers to design multidisciplinary modules and, we explored quality of these modules through this study.

Research Questions

The study aims to address the following research questions:

- What aspects of curriculum design mentioned in the National Higher Education Qualifications Framework Document is included in a multidisciplinary teaching module designed by undergraduate teachers?

Methodology

A series of three workshops were organized for teachers (n=85, experience- 5 to 15 years) from various disciplinary domains. The participants were introduced to the aspects of curriculum design, active learning pedagogies, assessment techniques, and SOCME diagram before they engaged with the development of a multidisciplinary module. Systems-oriented concept map extension (SOCME) explicitly brings out the interconnections between various sub-systems (Matlin, 2020). A problem statement was given to teachers based on themes that are inherently multidisciplinary, for example, agriculture, pollution, water management etc. Seventeen groups designed the multidisciplinary module. A rubric was devised for the assessment of the multidisciplinary module based on a) the quality parameters b) the graduate attributes described in curriculum documents (UNESCO, 2016; MoE, GoI, 2022). These graduate attributes have been identified as desirable by experts and is also recommended by UGC.

Findings

An initial group discussion indicated that the teachers do not have a clear understanding of what exactly is meant by a multidisciplinary approach. The modules by most of the groups of the first workshop fell short in including graduate attributes such as problem-solving, critical thinking, etc. Additionally, there was some inadequacy in the seamless weaving of different disciplines around the given theme. The next two workshops emphasized these aspects with the help of the SOCME diagram resulting in improved scores.

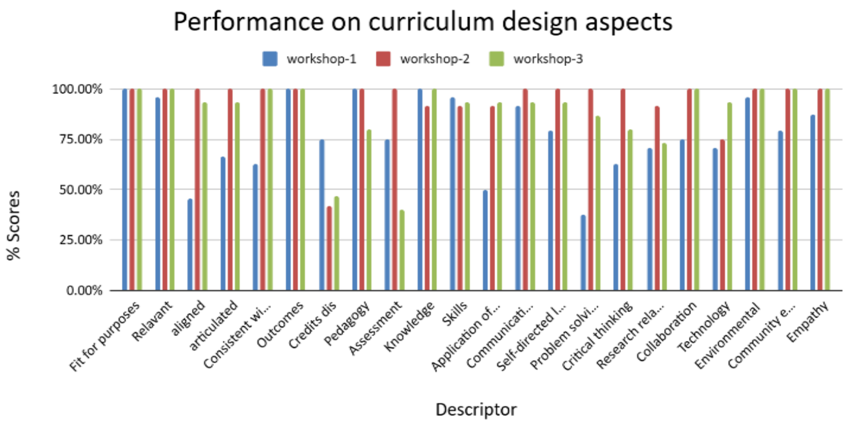

Fig. 1. Curriculum design aspects

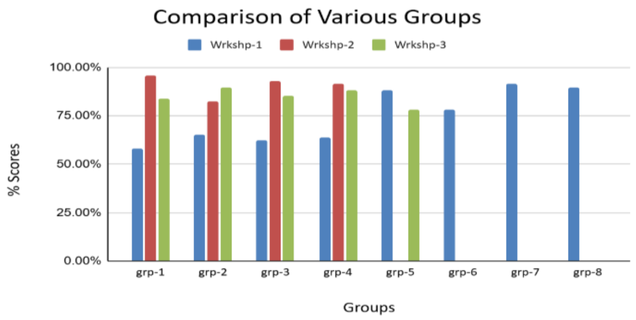

Fig. 2. Comparison of group performance

Conclusion

Undergraduate teachers need to be oriented toward what a multidisciplinary curriculum is. Through the SOCME diagram, teachers can visually see the connection between various disciplines around a theme. The result of our study suggests the feasibility of developing a multidisciplinary module by UG teachers wherein sciences, social sciences, humanities and engineering can be integrated easily. The module can be implemented. Further study with students can be carried out for understanding the learning outcome.

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Three-Dimensional Learning Approach to High School Organic Chemistry Through Flipped and Collaborative Classrooms

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High school students engaged in research-based flipped classroom and collaborative peer sessions, supported by well-equipped facilities. The hands-on learning approach effectively addressed misconceptions and enhanced students' conceptual understanding of organic chemistry. The learning outcomes were evaluated using the Three-Dimensional Learning Assessment Protocol (3D LAP) based on three-dimensional learning by National Research Council, USA. The student's performances were decoded to these dimensions and the results revealing significant improvements linked to the flipped and collaborative learning activities. Additionally, student feedback on the course was positive, indicating their favourable reception of this instructional method.

Keywords: Organic Chemistry, Flipped Classroom, Three-Dimensional Learning, High School

Introduction

Recent research studies provided evidence that the flipped classroom learning method is one of the successful students centered instructional strategies in chemistry education which aids students in developing their thinking abilities during the learning process (Bergmann, & Sams, 2012). Research reports indicated that the flipped pedagogy, as a distinct approach, allows for the integration of other learning methods (Seery, 2015). This study investigates the impact of combining collaborative activities with flipped learning for grade 10 students (N=12) in the basic organic chemistry course. In order to investigate the impact of structured peer work sessions, the learning outcomes were measured before and after merging the collaborative learning activities with flipped learning with the same set of students using three-dimensional learning categories.

Theoretical Framework

The flipped classroom concept gained popularity in 2007 and the term "flip" refers to the reversal of traditional learning, where students learn individually at home and engage in student−teacher interactions during class. This framework allows for the integration of other student-centric pedagogies to improve student performance. The term "three-dimensional learning" (3DL) was introduced in the K-12 Science Education Framework (NRC, 2012), combining disciplinary core ideas (DCIs), science and engineering practices (SEPs), and crosscutting concepts (CCCs). DCIs are the foundational concepts, while SEPs involve scientific methods to apply their knowledge, such as modeling, explanation, and data analysis. CCCs integrate these practices with core ideas. A Protocol was developed to measure how well assessments engage students in 3DL experiences (Cooper, Posey, & Underwood, 2017).

Methodology

The 15-week course featured two 90-minute sessions per week, integrating flipped learning with collaborative peer work. Pre-class activities involved watching online videos and the class time focused on clarifying doubts, quizzes, and interactive activities. Students worked in small groups led by peer leaders under instructor guidance. Qualitative analysis included evaluating pre-class activities, in-class interactions, Google quizzes, and communication with peer leaders, which helped facilitators assess student understanding, engagement, and participation. Quantitative analysis involved using the 3D LAP to assess student responses from evaluations. A rubric based on 3DL categories and a five-point Likert scale captured students' perceptions of their overall learning experiences in organic chemistry.

Findings

Student responses and classroom discussions confirmed that they followed facilitator instructions and linked prior knowledge with new information, aiding critical thinking. Pre-class evaluations showed familiarity with core ideas, which facilitators assessed to identify and address misconceptions. For example, the very common misconception in the initial stage of the course was about structural isomers. Later, collaborative learning activities such as atomic model kit exercises and computational 3D simulations helped students to overcome these misconceptions. The understandings on IUPAC naming the organic compounds were enhanced by atomic model hands-on activities and crossword puzzles during the in-class activities. In-class activities, including quizzes, debates, and collaborative activities, were designed to reinforce critical thinking (Fig. 1). The 3D LAP was used to measure understanding, revealing significant score improvements from 30.73 ± 12.65 to 46.15 ± 12.78 after peer sessions. Cronbach's α confirmed internal consistency in Likert scale feedback, which, along with open-ended responses. The overall performance showed that this blended approach effectively promoted scientific practices and crosscutting concepts for organic chemistry education.

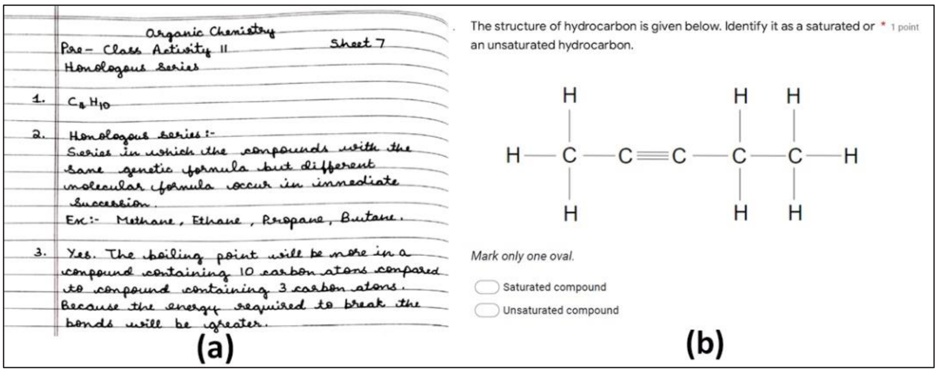

Fig. 1. Screenshot of (a) a student's response to a pre-class activity, and (b) a question from an in-class quiz.

Conclusion

The study showed that students effectively grasped core ideas through pre-class activities in the flipped framework. In-class and collaborative learning sessions successfully corrected most misconceptions due to interactive student-teacher and peer interactions. Hands-on activities were crucial for understanding challenging topics like IUPAC naming, structural isomerism, and organic compound properties. These activities enhanced conceptual understanding and engagement with 3DL practices. Statistical evidence and positive student feedback support the effectiveness of integrating collaborative learning with a flipped organic chemistry course, suggesting potential for broader application in chemistry education.

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Exploring Unit Circle and Trigonometric Functions' Relations with a Multipronged Educational Approach

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The mathematics textbooks and classroom discourse offer a limited platform for the students to explore the importance of unit circle in the area of trigonometry. Students often perceive triangle trigonometry, circle trigonometry, and graphs of trigonometric functions as disjoint entities, and discussions across the unit circle can help to show their interconnections. In the present study, we comment on how the unit circle is discussed in trigonometry chapters in textbooks and classroom discourse. Building on the analysis, we propose constructing some activities for students to explore the interconnections more explicitly.

Keywords: Trigonometry, Unit Circle, Triangle, Conceptual Connections

Introduction

Trigonometry is an area in school-level mathematics that deals with the relationships between angles and sides of triangles. It also serves as an important tool for explaining proofs of many laws in physics, astronomy, and engineering disciplines. Many studies in school-level trigonometry have discussed students' difficulties in trigonometry (Brown, 2006; Rosjanuardi & Jupri, 2022; Weber, 2005). To highlight a few, studies suggested students' limited understanding of sine and cosine as coordinates on the unit circle; as graphical distances; and as ratios of sides of a reference triangle. These and similar studies also indicate the importance of making the connections of unit circle with the linear distances and angles more elaborate for students. One of the approaches is the basics of trigonometry to be introduced using the unit circle trigonometric function definitions - connecting them to the ratio definitions - and then adopting the techniques of the ratio method for the solution of triangles (Kendal & Stacey, 1996; Rosjanuardi & Jupri, 2022). In the present study, we took a multipronged approach; firstly, we analysed the textbook discourse around unit circle in trigonometry chapters. We continued the studies by analysing the classroom discussions of triangle and circle trigonometry, interpretation of graphs of trigonometric functions, and conducted follow-up interviews with two teachers. Lastly, we developed a worksheet with 7 questions providing multiple opportunities for students to explore unit circle connections with triangle trigonometry and graphs of trigonometric functions and study students' responses.

Research Questions and Methodology

The study was guided by the following questions:

- How is triangle trigonometry aligned with circle trigonometry at the school level?
- What challenges do students face in the transition from acute-to-obtuse angle context?
- What challenges students face when they deal with trigonometric identity proofs?
- How do circle trigonometry connections with trigonometric graphs be discussed?

The textbook analysis involved a closer look of definitions and explanation of unit circle and its use in further concepts. We then followed observations of Grade 11, NCERT syllabus chapter titled 'trigonometric functions' (chapter 3) for 12 classroom sessions. The class had 27 students and was facilitated by an experienced mathematics teacher. The interview teachers included 2 mathematics teachers, out of which one teachers' class was observed. The school represents an urban school setting with English as a mode of instruction and is largely attended by students from families with sound socio-economic backgrounds.

Preliminary Analysis

During the classroom observations, we noted students' challenges in the transition from acute to obtuse angle trigonometry. For instance, while discussing the proof of $\cos(x+y) = \cos x \cos y - \sin x \sin y$ trigonometric identity, students agreed with the coordinates of angles 'x' as $(\cos x, \sin x)$ in the first quadrant (acute angles), but struggled with relating this notion in other quadrants. It was clear that students could not identify the coordinates of an obtuse angle 'x' as $(\cos x, \sin x)$. In the same proof, students did not connect with the key observations of needing to take the negative angle '$-y$' instead of '$-x$' even after probing on some occasions. It may sound trivial, but in a few instances; the students were hesitant to change the order of $\cos x + \cos y$ if the teacher started it as $\cos y + \cos x$. Some components of chapter 3 such as restrictions of identities and relevance of radian measure were not discussed in the class due to time constraints.

During the dialogue with teachers, one teacher mentioned not elaborating obtuse angle coordinates cases explicitly and it was mainly left for students to explore on their own. Similarly, teachers also expressed not being sure about their understanding of the need of a negative angle in the proof of identity. Furthermore, students are expected to find trigonometric ratios of 0° and 90° as special cases while discussing triangle trigonometry. However, teachers mentioned that students face challenges in accepting definitions built on approximations of trigonometric ratios when doing this exercise. Teachers also commented about the properties of triangles being eliminated from the recent curricula.

Discussions and Work in Progress

Based on the textbook analysis, classroom observations and follow-up teacher interviews, we felt that students have limited ways to appreciate unit circle and its connections with triangle trigonometry and trigonometric graphs. In classroom discourse, the connections of unit circle and trigonometric graphs are dealt as separate entities due to the textbook constraints. Further, the redefining of trigonometric ratios as coordinates of the unit circle is merely added as a one-liner without any emphasis on it and detailed explanation. Activities allowing students to explore more-detailed generalisation to the unit circle; and further to its connections with the graphs of trigonometric functions can be a useful addition. Moreover, it is important for students to first understand why such a generalisation, particularly of unit circle, is needed. Some key thoughts guiding the development of these activities spurred from the above observations, which are: a) the exercise of finding trigonometric ratios of 0° and 90° as special cases can be incorporated with the unit circle rather than dealing it in the triangle trigonometry. b) the properties of triangles (including sine and cosine rules) are being used in NCERT XI physics classes but their derivations being removed from previous mathematics courses may leave a gap in building appropriate connections, so a careful consideration for re-inclusion of properties of triangles is needed. With the cosine rule, students can easily derive the trigonometric identities.

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Collaborative Setting, Problem Solving and Generic Solutions

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In this paper, we analyse a collaborative problem-solving environment known as a Math Circle to explore the nature of mathematical reasoning and identify aspects of collaboration that foster the development of generalised solutions. The study was conducted with 32 ninth-grade female students. Often, problem-solving in school stops after finding a specific solution. However, the culture of the collaborative setting pushed students to question each other to identify forms and strategies for generalisation. The absence of teaching and an emphasis on micro- and macro-level collaboration, shaped the learning and solution outcomes.

Keywords: Math Circle, Generalisation, Students' Perception of Proof, Collaborative Setting

Introduction

Mathematics learning is often linked to anxiety and fear, mainly emerging from pedagogy that prioritises memorising of rules without their meaning. Research suggests that active engagement in mathematical problem-solving is more effective than passive learning (Walshaw & Anthony, 2008). Therefore, at HBCSE we started a collaborative, non-traditional learning environment called Math Circle (MC). Hansen (2022) highlights the role of collaborative, non-authoritative settings in fostering student agency and accountability. Building on this, we hosted a MC for girl students of grade 8 and 9. We examined how girls in the MC develop generalised solutions through collaborative discourse.

Theoretical Framework

The term MC is widely used across the globe, encompassing various forms such as math clubs, study groups, and more. At an educational research centre in Mumbai, an MC specifically for female students was initiated. Our approach aligns with the concept of MCs proposed by TIFR (MCI, 2022), where students collaborate to solve problems in a group setting. Here, problem-solving is central, and group discussions are encouraged, and at the same time teaching students on how to solve or providing solutions to them is avoided.

We added two distinct pedagogical features to the existing philosophy of MC: (1) No formal teaching; students to collaboratively explore and solve problems. (2) After each session, every group or student presents their solution or thought process to the larger group. The facilitators curated and selected problems appropriate for grade 9 students, adhering to a few implicit criteria. One key consideration was ensuring equitable access to mathematics in the problems.

Study Design and Methods

The work outlined in these abstract forms part of a broader study exploring mathematical reasoning in collaborative environments, where a total of 32 female students from various schools in Mumbai participated. These students were selected (out of 109) based on their responses to a math problem and questions, such as "What do you think mathematics is?" and "Do you enjoy mathematics? Why?". We looked for answers that are atypical and students wanting to enjoy mathematics rather hoping to gain marks or learn tricks for doing faster math.

All sessions were video-recorded. The problem analysed in this study was facilitated by the first author. Using the concept of "math overflow" (Tausczik et al., 2014), we analyse student discussions at both micro (small group) and macro (whole class) levels to capture the dynamics of collaboration.

In this paper, we focus on the discussion among five female students (four from the CBSE board and one from the ICSE board). We specifically ask the following research questions: (1) What is the nature of problem-solving in a collaborative setting?; (2) Which aspects of the collaboration contribute to developing generalised solutions?

Findings

The nature of problem-solving in such collaborative settings was not limited to solving the problem at hand, but to explore what generic form their solution can take. For e.g. lets see solution of this problem: “One litre of water is contained in each of two vessels. Half of the water from the first vessel is transferred to the second vessel, then one-third of the resulting water from the second vessel is transferred to the first, and so on. How much water will remain in each vessel after 100 transfers? Why?” Upon analysis, we found students (pseudonyms used) approached the problem in 4 different ways, and 2 of these were successful solutions.

Solution 1: One of the students started with a table, recording what happens to the volume in each vessel after every transfer. Upon discussion with peers, she moved to a generic table (see Table 1). She said at the 100th transfer, there will be one litre of water in each vessel because “We noticed a pattern that in even number of transfers, x remains the same; as the 100th transfer is even so, it will be equal 1-1(Saini)”.

Vessels	A	B
Let's consider	x	x
After 1st transfer	$\frac{x}{2}$	$\frac{3x}{2}$
After 2nd round, divide $\frac{3x}{2}$ by 3. So 3-3 get cancelled & transfer $\frac{x}{2}$ to A. In A, $\frac{x}{2}+\frac{x}{2}$ is x. In B also x remains.	x	x
3rd… after transferring $\frac{1}{4}$ to B	$\frac{3x}{4}$	$\frac{5x}{4}$
4th transfer	x	x

Table 1. Saini’s tabular reasoning in Solution 1

We think that the tabular representation – especially tracking quantities A and B this way, was one of the efficient ways to observe the pattern. And most importantly the table is also an evidence that the goal was always to find pattern, and not go till the 100^{th} transfer. This again shows how students gauged the generic aspect of the process.

Solution 2: Another solution used a specific quantity but generalised the number of steps for each transfer: "If I start with 1-1 litre then for n^{th} transfer, we transfer $\frac{1}{n+1}$ water. If n is an odd transfer then you take $\frac{1}{n+1}$ from 1 litre and get $\frac{n}{n+1}$ in first vessel. So when you add this to 1 litre you get $\frac{n+2}{n+1}$ in the second vessel. And now for even transfers you take $\frac{1}{n+2}$ of $\frac{n+2}{n+1}$ and add back to $\frac{n}{n+1}$ you get 1 litre and now both sides it is 1-1 litre (Ravee)".

Conclusion

Our observations revealed that the collaborative, no-teaching approach encouraged the girls to take ownership of classroom discussions. When one group presented a solution, others frequently questioned its generalisability and the underlying premises. Over time, this process led students to produce more generalised solutions, as seen in Solutions 1 and 2. Solution 2 is slightly advanced as the student not only used generalised water quantity but also generalised the number of steps or transfers, arriving at a solution that would then just require substituting n=100. Often, generalisation is made of an explicit pattern or of answer. We saw students generalising the process and distinguish special Vs general cases.

We saw development of a deeper understanding of mathematical proof, likely due to the consistent practice of convincing other groups of their solutions. Therefore, we propose settings such as collaborative math circles to develop aptitude for mathematics. With practice, the students of the math circle not only become successful problem solvers but also gain a sense of the nature of mathematics that is more aligned with the discipline—taking the emphasis away from rote learning and computing.

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Reframing "Gap" as "Distance" in Responding to Students' Mathematical Talk

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The notion of achievement gap has been criticised in the literature for its focus on the shortfall in achievement without due regard to the context, and the resulting deficit discourses. Building on scholars who have suggested ways of disrupting deficit discourses, we suggest reframing "gap" as "distance" as another means towards this. This shifts the focus to what students are capable of doing, which sometimes exceeds what is institutionally expected of them. It also opens up the possibility of the distance being bridged by the movement of both the teacher and the student. We also propose coherent formalisability as a metric for this distance.

Keywords: Disrupting Deficit Discourse, Achievement Gap, Coherent Formalisability

Achievement Gap and Deficit Discourses in Mathematics Education

The phrase "achievement gap" is used to denote the "gap" in academic achievement between dominant and marginalised groups of students. Disparities in mathematics performance have been the subject of scholarly attention and discussion. Criticising the term "achievement gap", scholars have pointed out to the "semantic and substantive" problems in the terminology and the dangers in maintaining an "achievement gap" focus (Gutiérrez, 2008; Ladson-Billings, 2007). The so-called "gap" offers a static picture of the inequalities and supports deficit thinking and negative narratives about marginalised students. Adiredja and Louie (2020) identify factors that lead to reproduction of deficit discourses especially in the case of mathematics education. The formal nature of mathematical knowledge and language; insistence on rigour in mathematical explanations; and seeking immediate, externally recognisable changes in mathematical understanding are key among them.

Considering ways to disrupt deficit discourses, Adiredja and Louie (2020) suggest continually expanding what counts as mathematical competence. Louie et al. (2021) suggest reframing mathematics learning as a creative exploration of ideas. Disrupting deficit discourses, calls for ways to make visible students' knowledge and understandings and to value their informal mathematical knowledge and emerging understandings. Addressing this need and building on the suggestions above, we propose reframing the notion of "deficit" in terms of "distance" rather than "gap" as a means to disrupt deficit discourses.

Reframing "Gap" as "Distance"

In contrast to "gap" which brings to mind a chasm or cleft, distance suggests something transient or variable, something that would be traversed or covered with passage of time. The distance metaphor evokes the picture of a span of movement. While a gap carries a negative connotation, a distance could be framed negatively as a "deficit distance" or positively as a "potential distance". An example of a deficit distance is the gap between grade level expectation of mathematical knowledge and students' knowledge as elicited through examinations. In contrast, the distance between what students are mathematically capable of and what is acknowledged by the institution (teachers, schools, exams) would be an example of potential distance. The distance metaphor also suggests that traversal may happen in both directions, of the teacher towards the student and her mathematics, as much as the students towards the formal mathematics that the teacher stands for. Drawing on instances from a two-year classroom experiment where students from marginalised backgrounds engaged in mathematical explorations, we illustrate an example of deficit distance, potential distance and two-way traversal.

A grade 9 student not being able to respond to" what percentage of 150 is 50?" using the standard formula or school taught algorithm is an example of deficit distance.
The same student figuring out that one percent of 150 is one-and-a-half and that twice one-and-a-half is 3 and repeatedly adding pairs of one-and-a-halfs till he reaches 50 and responding to the teacher that 50 is a little above 32% of 150, and above all insisting that he would solve the problem his way is an example of potential distance.
The teacher's willingness to give him the space and time to solve the problem in his way and being accepting of an unusual way of calculation at grade 9 level is an example of the teacher traversing the distance to the students' mathematics.

This episode also highlights the student's conceptual understanding, his non-standard ways of articulating it and the need to expand what counts as mathematical competence and mathematical language (Louie et al., 2021).

Formalisable Rather Than Formal

Reconceptualising the gap as distance also makes it measurable and allows for tracking the movement of students. When the goal is the formal mathematical discourse, the spontaneous informal discourses may seem "deficient". Jayasree et al. (2023) suggested Coherent Formalisability (CF) as a more accommodating acceptability criterion for students' mathematical discourses. CF criterion allows space for informal and incomplete utterances thereby making visible the knowledge and understanding students bring thereby mitigating deficit discourses. Defined as "the potential of a section of discourse to be mapped to a formal one by supplying missing terminology, definitions, and reasoning, in a uniform manner", it also functions as an indicator of distance from the formal mathematical language. It orients students towards formal mathematical discourse without making it the ultimate goal. The extent of missing elements that need to be supplied to map the discourse onto the formal mathematical discourse gives a sense of the distance that needs to be bridged. Thus, in addition to being an abstract acceptability criterion, we suggest that CF could also function as a "measure" of the distance from the formal language. While it remains to be seen whether a teacher in a classroom situation can deploy metrics to assess a student's distance from use of formal mathematical language, it can help her reflect on classroom practice and offer ways of listening and noticing. This needs further exploration.

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From Algorithms to Inquiry: Reintroducing Geometric Constructions Through Indian Knowledge Systems

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Often mathematics textbooks directly jump into teaching most of the concepts without discussing the history or motivation to pursue the topics. The teaching and learning thus ends up being restricted to more of procedural ways thereby taking away the element of joy in mathematics. In this paper, we share findings from a decade-long experience of integrating ideas from the history of mathematics from Indian Knowledge Systems to build inquiry, higher order thinking skills and hands-on learning. We also highlight how the topic can be re-introduced under the light of ideas from Indian Knowledge Systems and guiding principles by NEP 2020.

Keywords: Mathematics Education, Geometric Constructions, Indian Knowledge Systems, Sulba Sutras.

Introduction

A strong foundation in mathematics from an early age is crucial, yet many students find the subject challenging. Making mathematics meaningful, relatable and engaging remains a significant hurdle. Typically, mathematics education over emphasises procedural learning and assessments, which test procedural skills rather than fostering mathematical thinking. This approach can lead to student boredom and a lack of real-life relevance (Gainsburg, 2008). Educators need to incorporate activities that not only engage students but also provide motivation and context for learning.

This paper examines geometric construction – a topic removed from NCERT textbooks in 2023 – and explores how incorporating Indian Knowledge Systems (IKS) can enhance student engagement through inquiry-based and experiential learning. We share teaching experiences that integrate the history of Indian Mathematics into the classroom, offering insights for educators and textbook writers to make mathematics more interactive and meaningful.

Theoretical Framework

The theoretical framework for this paper is based on guided discovery. In guided discovery learning students are able to engage actively and constructively in the learning process, allowing them to integrate and build their own understanding (Shieh, 2016). Guided discovery learning follows the structure of the scientific method, where students work in groups to solve problems through a series of steps, starting with stimulation, problem identification, data collection, data analysis, verification, and concluding with drawing conclusions (Yerizon, 2018).

Research Questions

The paper aims at addressing the following research questions:

- How can integrating IKS into geometry education enhance student engagement and understanding?
- In what ways can the historical methods of geometric constructions from the Sulba Sutras improve students' comprehension of geometric concepts and theorems, such as the Pythagorean Theorem?
- How does incorporating inquiry-based, hands-on learning methods based on IKS motivate students and make mathematics more meaningful and relevant to their lives?

Methodology

The methodology revolves around integrating knowledge from ancient India texts like the Sulba Sutras (Datta, 1932) and texts on Yantras that offer practical applications and historical context for geometric constructions (Gupta, 2007) which can be used to enhance student engagement and understanding. Key aspects of the methodology include integrating IKS in classroom activities using hands-on, inquiry-based and experiential learning where students actively engage in exploring geometric constructions and problem solving. The methodology combines historical content, inquiry-based learning, hands-on activities, and real-world connections to teach geometric constructions and foster a deeper understanding of mathematics through the integration of IKS.

Here's one of the activities related to construction of a square.

When asked to construct a square with a rope, students generally struggle initially. They are then introduced to Baudhayana Sulba Sutra’s method of using intersecting circles. After grappling with the complexity of the method, students appreciate its ingenuity. The teacher guides them step-by-step, revealing how circles can identify the vertices of a square. Students first practice in notebooks and then apply their knowledge on an open ground, enhancing their engagement through a hands-on approach. There is nothing like doing the construction on a bigger canvas and the students always enjoy the activities.

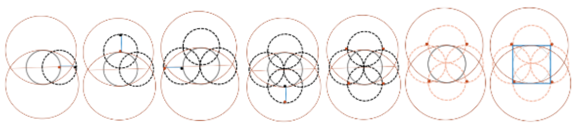

Fig 1: Constructing a square Fig 2: Constructing Octagram Fig 3: Construction procedure from Sulba Sutras

The paper contains more activities include constructing geometric shapes from Sulba Sutras to represent the Pythagorean Theorem. While some constructions, like the hexagram and octagram, are intuitive, others, such as creating a square with area as a difference/sum of two squares, require deeper understanding. Students love such activities that demand hands-on and minds-on learning.

Findings

- Enhanced Understanding: IKS-based constructions help students grasp geometric concepts better by linking them to historical methods and applications.
- Reinforced Theorems: Construction methods from the Sulba Sutras offer alternative representations of the Pythagorean Theorem, improving comprehension.
- Motivation and Purpose: Activities rooted in IKS provide students with clear purposes and motivations, making mathematics more meaningful.

Conclusion

Despite time constraints in school curricula, incorporating IKS into geometric constructions offers substantial benefits. These activities foster inquiry and higher-order thinking, connect students to historical knowledge, and provide engaging, hands-on learning experiences. IKS methods can be adapted to modern contexts, such as constructing clocks or geometric rangoli, making math more accessible and enjoyable. Ultimately, these approaches help students understand algebraic identities and the Pythagorean Theorem from a new perspective.

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Enhancing Engagement in Biology: Utilising Contextual Settings to Spark Interest in Theory and Lab Courses

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This study explores the role of "setting context" in biology education as a strategy enhance student engagement. By illustrating the relevance and real-world applications of complex topics, students develop a deeper understanding and interest. The study suggests several pedagogical methods, including the use of audio-visual aids, real-life case studies, storytelling, and experiential learning activities, to set context effectively. These approaches help students grasp challenging concepts, such as biochemistry and genetics, by linking them to practical, relatable scenarios. For example, using case studies, stories of scientific discoveries, hands-on activities can engage students in meaningful learning. The study highlights the significance of setting context as a tool for promoting active learning, student curiosity, and outcome-based education. While resource-intensive, these strategies are shown to improve student engagement, making challenging biological concepts more accessible and impactful.

Keywords: Setting Context, Active Learning, Biochemistry, Genetics, Experiential Learning, Pedagogical Strategies.

Introduction

Biology is an interdisciplinary science where various concepts from natural sciences converge to explain biological processes. Students of biology often experience anxiety when faced with topics that involve complex terminology, intricate processes, or foundational principles from physics, chemistry, or mathematics. This anxiety can lead to an aversion to such topics, causing students to lose focus and interest in class. Much of this fear originates from a lack of confidence in their ability to comprehend the concept and a limited understanding of the relevance and significance of these concepts (Broman et al., 2022). However, it has been observed that when students realise the significance of understanding these concepts, their role in biological context and how they can be applied to real-life situations (Wangda et al., 2024), it sparks an interest in learning. This newfound interest not only enhances their understanding but also improves their ability to apply the concepts in a meaningful way. The method of setting context in classrooms becomes crucial for effectively engaging students and involving everyone in the learning process (Wurm et al., 2017). When a student can articulate why they are learning a particular concept, it indicates that they were actively engaged in the learning process.

Contextual setting as a teaching tool helps students understand how and where a concept can be applied, aiding creative thinking to solve social and environmental issues (Tran et al., 2024). Although setting context for all topics can be challenging and resource-intensive for educators, it ensures effective student engagement and promotes outcome-based learning.

Theoretical Framework

This study is based on the theory of Backward design formulated by Wiggins & McTighe in 2005. Relevance of concepts can be outlined with regards to the meaningfulness, significance, societal impact and ability to ignite interest among the students (Broman et al., 2022). Hence identifying apt resources to set the context for a given topic requires time and planning. These methods and resources can be incorporated as a part of the lesson plan which can then be modified with timely inputs from students, peers and self-reflection on the experience post execution.

This study focuses mainly on how the teaching learning resources usually used in classroom teaching can be repurposed to set context and background for topics normally considered to be complex in terms of understanding. Using different types of resources to set background for theory & laboratory topics related to biochemistry are suggested in this study which can be impactful in aligning student interest to the concepts.

Research Questions

The study aims to address the following research questions: Can setting context help in keeping students engaged during the discourse of challenging concepts leading to active learning? Which pedagogical strategies are effective for setting context for complex biology concepts?

Methodology and Findings

To set context in theory and lab sessions, the following methods can be effective:

1. *Audio-Visual Aids:* Use videos to illustrate concepts like genetically inherited diseases or membrane transport in cell biology, helping students visualise processes and understand their significance, sparking interest and questions. In cell biology, use of a visual of generation and propagation of nerve impulse and how multiple impulses travel across the CNS was impactful in setting background to discuss action potential and raised curiosity among students about what will happen if these impulses collide with each other.

2. *Real-Life Incidences:*

   - **Newspaper/Science Magazine Articles**: Articles related to epidemics or real-world events, like the Thalidomide disaster, can engage students by showing the relevance of the concepts to real life. (Wangda et al., 2024). This example has been very useful in setting the tone for studying stereoisomerism as students relate to the significance of the concept.

   - **Story Narration**: Narrating stories about outbreaks or tracing infections can make theoretical concepts like epidemiology more relatable and easier to grasp (Liu, 2023). Discussing how patient zero for Covid 19 infection was traced and the source of the infection was demystified has helped students in understanding the core concepts of epidemiology.

- **Tales of Discoveries**: Sharing the stories behind biochemical discoveries helps students appreciate the efforts and methods involved, deepening their understanding of the subject. The example of how different aspects of photosynthesis was studied by different researchers which together made a sense of the overall reaction of photosynthesis or how were phytohormones discovered accidentally has been pivotal in keeping students interested towards concepts which are normally considered dry or uninteresting.

3. *Use of learning activities:*
   Learning activities is one of the ways of invoking curiosity among the students about a concept. Activities like reaction sheets, think-pair-share/repair encourages learners to collaborate and increases peer learning. Structured questioning or activity sheets help assess prior understanding and misconceptions. Flipped classroom promotes interesting discussions in class and ignites curiosity.

4. *Use of experiential learning:*
   Stereoisomerism as a concept for biology students can be dry and difficult to relate to. Use of hands-on experience can be very effective in explaining them the concept: Visualising tartarate isomers under the microscope, taking selfies of objects and superimposing them, smelling essential oils having different isomers of the same compound, understanding passage of light in coloured solutions using laser light and coloured solutions of different concentrations. Use of such techniques to teach biochemistry has been very impactful as students as it makes them take more interest in understanding the chemical structures and the reactions being discussed. They also have explored other isomers in products which they come across in daily life and how they differ in functionality.

Conclusion

Incorporating contextual settings in biology education, particularly in theory and lab courses, plays a crucial role in enhancing student engagement and comprehension. Although setting context for every topic may require additional resources and planning, the benefits in terms of improved student interest, engagement, and outcome-based learning make it a valuable pedagogical strategy.

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Unpacking Pedagogical Context: An Empirical Study of Middle School Biology Class

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Sometimes teachers go beyond the process skills to make the students understand the science concepts in a better way. Teachers try to situate the content/concepts of science in various contexts so that the science content becomes relevant to student's real world. This paper is part of the researcher's ongoing work on pedagogical contexts provided by the teacher and the factors influencing the teacher to facilitate pedagogical context as part of pedagogical practices while teaching classes 7 and 8 biological concepts. The study adopts a qualitative research design that involves classroom observation and conversational interviews with teachers and students.

Keywords: Pedagogical Context, Pedagogical Practices, Students' Real World, Middle School, Biological Concepts.

Introduction

The main objective of NCFSE, 2023 is to transform the school education system of India as visualised in NEP-2020 through a positive change in the curriculum, including pedagogy and real-life connections in various contexts. To expand the pedagogical activity beyond the classroom, teachers often provide a context from various sociocultural settings to explain the concepts. Providing a context and establishing a relationship with the subject, school, and outside-of-school context is a growing concern in research and educational practice (Rajala, 2019). Science teachers often use pedagogical contexts to help engage teachers and support content transfer in the science classroom. However, few studies have explored how pedagogical contexts influence student engagement and science content learning. Many professional development programs for science teachers situate the content of science in a suitable context for a better understanding of concepts (Duzor, 2012). What science teachers do is situate science in everyday classroom life, including educational contexts and microworlds. Pedagogical context knowledge enables teachers to look around the two elements of the knowledge landscape. These include societal and academic elements (Barnett & Hodson, 2001).

Teachers struggle to teach biology based on real-world context. Their background is primarily academic, lacking real-world application. They could not investigate scientific problems in the real world (King et al., 2007). Contextual Teaching Learning is consistent with constructivist processes (such as critical thinking, inquiry learning, and problem-solving). These processes must be in students' physical, intellectual, and social contexts (Cobb & Bowers, 1999; Kumar & Voldrich, 1994, Brown, 2000; Cavallo et al., 2002; Downing & Gifford, 1996; Driver et al., 1994; Glynn & Duit, 1995). The CTL is a basic approach that has come from teachers' struggle to situate the instruction in children's life contexts by using various strategies, such as inquiry-based learning, problem-solving, project-based learning, and collaborative learning. These strategies must address student differences and contextual diversity (Chiappetta & Koballa, 2002; Loucks-Horsley et al., 2003).

CTL is not a readymade approach to teaching science. Rather, its fundamental techniques provide a set of unified approaches that middle school teachers can use to teach successfully and address controversial yet central issues that may arise in their classrooms - issues such as the origin of the earth, the evolution of life, and animal rights, to name only a few. The CTL techniques were best executed when teachers apply them concomitant with proper classroom management strategies. The execution of CTL techniques can assist middle school teachers in addressing the challenges that encounter when teaching science to children. (Glynn & Winter, 2004). In this paper, the researcher discussed the pedagogical context provided by the teacher during the teaching of class 7 and 8 biology lessons. Based on the observations, the researcher discussed a variety of pedagogical contexts provided by the teacher as part of pedagogical practices during the teaching of class 7 and 8 biological concepts. Biology is the scientific study of life. It focuses on various aspects of life. Biology is a quest, an ongoing inquiry about life (Campbell & Reece, 2005, p.2).

Theoretical Framework

In this paper, the researcher explores the pedagogical context provided by the teacher and students' real world based on the 2 theoretical approaches.

1. Vygotsky's theory of social constructivism in classroom application is useful for preparing teachers as facilitators as per the changing role of a teacher in the present socio-cultural classroom, including the learning activities to be carried out and peer interaction. This shows the teachers, how a teacher can best understand the sociocultural context of the classroom and how well he/she can use that context and indigenous knowledge to foster learning, conceptual understanding, and application of basic skills and conducting basic investigations of the science subject that led to the achievement of desired learning outcomes (Kozulin et al., 2003, p.9).

2. Culturally relevant pedagogy proposed by Ladson-Billings (1995). Culturally relevant pedagogy in science seeks to connect science education with students' cultural identities, interests, and everyday experiences. It aims to engage students by making science relevant and meaningful to their lives. Teachers establish connections with their students' cultural origins and language as part of their everyday classroom practices. CRE in the 21st century requires awareness, knowledge, processes, and techniques to focus on integrating language and culture in the classroom reality in the context of globalisation (Akcan, 2022).

Research Objective

To understand the pedagogical context facilitated by a science teacher in the middle school biological science classroom.

Research Questions

- What are the different pedagogical contexts used by the teacher in biological science class?
- How does pedagogical context shape the pedagogical practices of a science teacher?

Research Methods

A private school in the Ranga Reddy district of Telangana was the location of the study. The school has a separate section for boys and girls, and the school is in an area where all the students belong to the Muslim community. The school follows the SCERT curriculum. As part of the qualitative research design, the researcher conducted classroom observation and conversational interviews with teachers and students. The researcher collected the data through audio and video recordings to understand the pedagogical context facilitated by the science teacher of classes 7 and 8. The researcher uncovered some themes from classroom observation through thematic analysis to understand the patterns of pedagogical context provided by the science teacher.

Preliminary Observations

Embedding the content in different contexts, including religious, sociocultural, and cultural metaphors, as well as the researcher has noticed the school and community's immediate surroundings. The pedagogical context they create also influences the teacher's pedagogical practices. The teaching-learning strategies become student-centered and the students can understand and express the concepts in their own words. For example, to explain the concept of saprophytic nutrition, the teacher gave the example of the dead bodies of buried people. The teacher used the context of Muslim burial grounds and asked what happens after burying the dead bodies. Do we find dead bodies or something else? During the discussion of the legal age of marriage, the teacher asked the students, "You might have seen some months ago there was a line in front of the community mosque because of the announcement made by the government regarding an increase in the legal age, people rush to get married. "The government has raised the legal age for marriage because our bodies are not fully developed by that age. Similarly, the teacher has provided different contexts for different topics. The researcher also observed the factors that influence the teacher's facilitation of pedagogical contexts, such as the students' backgrounds (language, community resources, religion, and culture), the non-availability of teaching-learning material, the lack of laboratory facilities, and teacher beliefs. The teacher has considered all the above aspects to provide the pedagogical context to suit the students' real-world situations.

Conclusion

The study provides valuable insights into various pedagogical contexts facilitated by the science teacher while explaining biological concepts at the middle school level and helping the students understand science concepts better. Further exploration of these pedagogical contexts can reveal the necessity and significance of using contexts in science classrooms, as well as the factors influencing teachers' decisions to use various contexts for explaining science concepts.

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Development of Academic Laboratories in Chemical Engineering Simulation and Process Control at IIT Ropar: Achievements and Learnings

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The Department of Chemical Engineering at the Indian Institute of Technology Ropar was established in 2017 in Rupnagar (Punjab). Four academic teaching laboratories seminal to chemical engineering - Fluid Flow, Heat and Mass Transfer Laboratory, Chemical Reaction Engineering Laboratory, Process Control Laboratory and Chemical Engineering Simulation Laboratory were developed to help undergraduate education. The author was given the responsibility to develop the Process Control and Chemical Engineering Simulation Laboratory. The courses in these academic laboratories are based on process systems engineering (Process Modeling, Control and Optimisation). This presentation essentially chronicles the development of these laboratories - the opportunities utilised on digitalisation, and the challenges encountered. The motivation of the presentation at epiSTEME 10 is to help future STEM practitioners for initiating a dialogue on academic laboratory development aimed for achieving high quality educational objectives. A perspective on the emerging STEM Workforce and the impact of Artificial Intelligence and Digitalisation in Chemical Engineering and efforts at IIT Ropar will also be presented.

Keywords: Digitalisation, Process Simulation, Process Control, Chemical Engineering Education

Introduction

The Indian Institute of Technology Ropar was established in 2008. In its pursuit of expanding the reach and enhancing the quality of education, a generic educational curricular framework was conceptualised between 2015-2017 (Prasad et al., 2018), encouraging novel ideas to be implemented. In July 2017, the Department of Chemical Engineering at IIT Ropar was established. The first student intake in the department was initiated in August 2017, and the academic laboratories on Chemical Engineering Simulation were taught for the first time in August 2018 and Process Control Lab was taught for the first time in January 2020.

Implementation

The Chemical Engineering Simulation Laboratory at IIT Ropar in the Transit Campus was developed as two learning zones with 28 and 18 computers each. This designation was made to help undergraduate students and research scholars access the computing facilities. From a teaching and learning point of view, in addition to the available reference material as a new department it was valuable to reflect upon the historical literature on chemical process simulation (Seader, 1989). The insights documented in literature has helped in informing the evolving nature of chemical engineering from its beginnings in Industrial Chemistry, conceptualising the discipline in terms of unit processes and operations and solving them through a computer to the current understanding of incorporating digitalisation in course curricula.

While conceptualising a new laboratory, a few issues were faced. In a new department recruitment of laboratory staff takes time. Identification of laboratory space and obtaining computers to commence operation also posed a challenge, especially in an academic institution where multiple departments in an institute are being established simultaneously. It was also envisioned that from a pedagogical view point, numerous paradigms on utilisation of chemical engineering simulation software have been documented in literature (Seader, 1989). These paradigms involve utilising simulation to address industrial problems, simulating laboratory experiments, incorporating blended learning and problem-based learning to the other extreme of students understanding the background of the software and not treating the academic course like a "black box". It is also important to reiterate the importance of convergence in Chemical Engineering Simulation Center as a "convergence" to assist instruction in core and elective courses. The evidence in chemical engineering educational literature on the integration of computers to assist classroom learning is plentiful ranging from bioprocess engineering, fluid flow, separation processes, and petroleum refinery engineering (Fernandes, 2002). Moreover, it is expected that the modern laboratory should be in a position to cater to advances in open-source software (Freire, 2014) and evolving application using Python notebooks in Chemical Engineering are expected to influence developments (Domínguez, 2021)

The Chemical Engineering Process Control Laboratory at IIT Ropar in the Transit Campus has been developed as two designated areas: one to impart digital learning experience in accordance to Industry 4.0 and the other to give a physical learning experience. In the course of five years, the author has explored various software like MATLAB, SIMULINK, Loop-Pro (Control Station) and PI-TOPS and SIMCET (Pi Control), Dynamic Simulation in DWSIM. The usage of LABVIEW, Harold and ASPEN Suite are currently being explored. These cover suggestions on a wide variety of exercises ranging from classical problems to model predictive control. On the use of software, two contrasting views have emerged: one is that in undergraduate education if the students are introduced to industry-based simulators then the initiative and motivation to learn what is happening in the background decreases. The other viewpoint is that some industrial based software should be taught to the student to retain motivation (Abdulwahed & Nagy, 2014).

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Energy Mentors: An Initiative on Collaboration with Academia and Industry to Train Future Energy Professionals

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In April 2023, professors from IIT Ropar, iHub – AWaDH, a Technology Innovation Hub established by the DST – Government of India at IIT Ropar in the framework of National Mission on Interdisciplinary Cyber-Physical Systems, and the Energy Mentors, a US based non-profit organisation, entered into a Memorandum of Understanding (MoU) to identify and encourage talented students from South Asia and Africa. The aim of this MoU is grounded in the hypotheses that to the degree we can grow more energy professionals where they live with better capabilities and competency, the better positioned under-resourced communities could be to solve their energy trilemma: access to affordable energy, resiliency and assurance in energy supply, and to obtain such energy sustainably and at lower greenhouse gas (GHG) intensity. This study summarises the first and second implementation of International Energy Mentors Internship Program in May 2023 and May 2024.

Keywords: Virtual Internships, Energy, Sustainable Development, Engineering Education

Introduction

The International Energy Mentors Internship Program of was initiated in May 2023. Student participants were solicited via social media with the aim to identify a pool of hundred students who may work on an interdisciplinary energy problem. The interdisciplinary energy problems were scaled down versions for the premise published for "Power the Community", an international college design competition created by Energy Mentors that will be conducted during the 2023-2024 academic year. Professionals with deep industrial experience were able to virtually lecture from locations across India, the United Kingdom, and the Unites States students spread across South Asia and Africa. Modern meeting plat-forms hosted upwards of 240 participants simultaneous and facilitated questions to the presenters via chat and upvoting mechanisms.

Deliverable Structure

Table 1 gives the form of generic deliverables from an Energy Mentor Project. This finds its basis in engineering education literature (Medeiros, Ìcen, Morciano & Cortesão, 2015).

Stage	Typical Deliverables
Stage 1	Order of magnitude study, identify the use case, list customer requirements, initial energy balance, system sizing, understanding the supply and demand side of the problem
Stage 2	Generating the equipment list, sizing of component, layout, circuit diagrams / process flowsheets
Stage 3	Digital twin of the energy system along with dynamic performance, structural, electrical design, system ratings

Table 1. Generic deliverables from an Energy Mentor Project

Methods and Findings

The first week of the program included lectures from energy professionals from the solar, wind, process simulation, agri-photovoltaics, electric vehicles, battery storage and energy transition industry, distributed energy systems. The initiative was fostered by participation of organisations who provided software (e.g., Dassault Systèmes and MathWorks) for the first week of training, more than 200 students inducted and given know-how of energy sources, utilisation, optimisation and potential issues in the domain.

The organisers subsequently organised a screening assessment on the basis of review of the assignment performance of the participants in which 90 scholars from South Asia and Africa were selected for complete training program. The results of the screening assessment were declared by June 1 and the students are currently undergoing the seven-week multidisciplinary group project. Eighteen teams of five students each are working on the design problem in the Energy Mentors competition. The problem statement of this year includes to design an energy solution for a community of 2000 individuals. Out of the 90 students selected, 81 students are from India, 2 from Bangladesh, 2 from Ethiopia and 1 from Cameroon, Belgium, Sudan, Nigeria and Kenya.

Fig. 1. showcases the discipline-wise distribution.

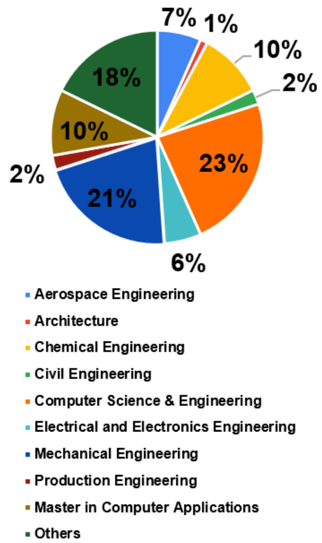

Fig. 1. Discipline-wise contribution to Energy Mentors in 2023

Conclusions

Through a presentation on this study, the authors intend to showcase to the STEM Community the impact of the Virtual Internship Program and its impact on engineering education. The learnings and challenges associated with the author's effort will be discussed at the epiSTEME Conference.

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Introduction of Systems Thinking Exercise in an Undergraduate Pharmacy Laboratory Course

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The current report describes the attempts to introduce systems thinking in an undergraduate Physical Pharmacy laboratory course. The students were introduced to the idea of systems thinking during discussion sessions using a hands-on example. The students were encouraged to work in groups of 5 to design their own example with a focus on at least one physicochemical aspect studied in the lab sessions. The combination of the systems thinking in the laboratory courses is an effective way of linking the cognitive, psychomotor and affective domains of learning. The challenges faced in implementation of the exercise and means to overcome the same have been explored.

Keywords: Systems Thinking, Chemical Education, Pharmaceutical Context, Hands-on Learning

Introduction

The evolution of technology has amplified the interconnected nature of real-world systems in the past century. In the meanwhile, the teaching of scientific disciplines has become increasingly specialised and by extension, reductionist. Systems thinking approach has evolved as an alternative format of discussing scientific principles which encourage a holistic perspective and emphasise on the complexity of real-world problems (Orgill, 2019). Incorporation of systems thinking in STEM education would include examples like life cycle analysis of chemicals, process of drug approval or policy matters in health sciences.

The use of systems thinking approach for teaching pharmaceutical chemistry and allied topics to students is a natural and logical extension of the systems thinking approach (Talanquer, 2024). The fact that the pharmaceutical industry is related to many social, economic and ethical aspects makes it particularly relevant for the students of this stream (Holme, 2020).

Theoretical Framework

An essential aspect of systems thinking approach is the recognition of the complexity of real-world systems and the ability to treat this complexity without resorting to reductionist style of thinking. The students will identify the important components (or sub-systems), explore the inter-relation and finally, understanding the hidden correlations. The ultimate skill expected from the exercise is the ability to make generalisation and predict the probable outcomes in given set of conditions.

The use of appropriate tools for constructing and visualising the sub-domains is critical in such exercises. The use of System-Oriented Concept Map Extension (SOCME) is known to be one of the most efficient tools in this regard (Mahaffy, 2019). The lucid representation of concepts, ability to collaborate and the ease of access of SOCME tools was an important advantage in the current project.

Methods and Findings

The present repot is based on the attempt to introduce the holistic systems thinking approach as part of the undergraduate curriculum. The Physical Pharmaceutics laboratory course is a third semester course for the students enrolled in the Bachelor of Pharmacy program. The same students (37 students for the current batch) are also taught the Physical Pharmacy theory course in the same semester which is taught by a different instructor. The prescribed syllabus for the laboratory course includes experiments designed to determine physicochemical properties such as solubility, pKa, ionization, complexation and partition coefficients. The chemical systems chosen to be of relevance in terms of their pharmaceutical applications.

In order to introduce the students to the systems thinking approach, a discussion session was organised by the instructor after the students had completed the majority of the lab experiments. The timing of the discussion was such that the students already had the hands-on experience required for the discussion but also had the option of revisiting the experiment / data if they felt the need to do so. Each session lasted for an hour and the students were given a week's time to submit their feedback / observations.

1) In the first session, the students were introduced to the SOCME tool and a general discussion on how real-world systems should be treated as a whole rather than sum-of-parts. The discussion of diclofenac as a drug molecule was initiated. Guiding questions were given to the students who were encouraged to develop the SOCME diagram with their group members and share with the rest of the peers.
2) The next session continued with the compilation of the more important components in the SOCME for diclofenac – it was observed that the chemical and pharmacological aspects were the more obvious sub-systems. The discussion however continued to explore other socio-economic aspects such as overuse, production norms and quality control, cost analysis – these topics mainly pertained to the Environment, Economics and Ethics sub-systems.
3) In the final session, the students were expected to explore the linkages between the different sub-sections and the factors that connected them. The parts with greater relevance to the Physical Pharmacy course were also highlighted. At the end of this session, the students were asked to take up any other drug molecule or property and explore the different aspects of the system as a group assignment.

Efficient implementation of the exercise relies heavily on two IT tools – the use of SOCME for collaborating and explaining the interconnections and the use of Google Classroom as an online LMS for sharing assignments and feedbacks. Discussion with the instructor or TA is very much encouraged.

The assignments submitted by students were shared with their peers for feedback and discussion. The students could choose to edit / modify their submission based on their observations (of other submissions) or the suggestions of their classmates.

A brief discussion of the assignments was be taken up as a final session followed by a reflective survey. The purpose of the survey was to gain the students' perspective about the implementation and applicability of systems thinking.

Conclusion

Increase in student engagement was observed during the discussions and it was reflected in their laboratory skills. Students are observed to be more intent when performing experiments since they are now more conscious of the real-world relevance.

The formal feedback of the students collected anonymously and students reported an improved understanding of the different concepts. The challenges and limitations felt in the first implementation were minimal and could be improved with time and better design of the activities.

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Enhancing STEM Education Through the Practice-Based Professional Development for Secondary STEM Teachers in Bhutan

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This study explored the perceptions and experiences of a select group of secondary STEM teachers in Bhutan who participated in a practice-based professional development (PD) program facilitated through Open Educational Resources (OER) modules. The PD aimed to enhance teachers' Knowledge, Attitudes, and Practices (KAP). Teachers reported that the program was highly relevant, improved their teaching practices, and helped them apply newly acquired skills in the classroom. Despite challenges such as time constraints, peer-review requirements, and technical difficulties, the findings provide valuable insights into the effectiveness of practice-based PD and its potential for broader implementation in Bhutan.

Keywords: Practice-based Professional Development, Open Educational Resources (OER), Secondary STEM Teacher

Introduction

Professional development (PD) for STEM teachers is essential for improving their capacity to deliver high-quality teaching and foster effective learning. Despite the recognised importance, many existing PD programs often fail to address the specific needs and challenges faced by STEM teachers. In the Bhutanese Education System (BES), PD programs have traditionally been delivered through centralised workshops. However, there has been no structured mechanism to ensure that teachers apply the newly acquired knowledge and skills in their classrooms. In contrast to this conventional approach, a practice-based PD initiative was jointly implemented for the first time by the Ministry of Education and Skills Development (MoESD) and a teacher education college in Bhutan. This new model aligns with research critiquing traditional PD approaches, which are often short-term, delivered in a top-down manner, and do not require teachers to implement, reflect on, or refine skills through ongoing cycles of planning, practice, and reflection. Research indicates that practice-based PD, which integrates theoretical learning with practical application, can greatly enhance classroom practices, leading to better teaching quality and improved student outcomes (Ajani, 2023). Additionally, such programs promote reflective learning, strengthening teachers' professional competencies.

Theoretical Framework

The theoretical framework for this study is grounded in the Theory of Change, which posits that specific interventions lead to desired outcomes. Drawing from the work of Shulman (1986), who emphasised the importance of Pedagogical Content Knowledge (PCK) for effective teaching and Universal Design for Learning Principles (CAST [Center for Applied Special Technology] 2018), Open Educational Resources (OER) modules were curated to support teachers' PD. Furthermore, Ramchand's (2022) works guided the transformation of teachers' knowledge, attitudes, and practices (KAP) in the implementation of practice-based PD using OER.

Theoretical Framework, Research and Research Questions, Original Aspects

In alignment with the Theory of Change, the conceptual framework was developed drawing on the works of Shulman (1986), CAST [Center for Applied Special Technology] (2018), and Ramchand (2022) to transform teachers' knowledge, attitudes, and practices (KAP) through the use of OER modules within a practice-based model.

Research Questions

The primary research question for the study was:

- What are teachers' perceptions and experiences regarding the effectiveness of the practice-based professional development program facilitated through OER modules?

Methodology

A total of 148 secondary STEM teachers were selected by the ministry and a partner education college through open applications for a practice-based PD program. The PD utilised four OER modules for each subject: biology, chemistry, physics, and mathematics, curated by aligning with the national curriculum framework and using principles of Universal Design for Learning (UDL). Teachers had six weeks to complete each module, including pre- and post-tests, developing and implementing two lessons, and writing a reflection. Additionally, their lesson plans and teaching recordings were reviewed by peers and tutors. Halfway through the ongoing PD program, teachers were administered a survey questionnaire that included both open-ended and closed-ended questions.

The survey focused on the following themes: relevance of the program, application of skills, usefulness of the content and design of the PD, and challenges encountered. Closed-ended questions were analysed using descriptive statistics, while open-ended questions were analysed thematically.

Findings

The results indicated that 95.4% of participants found the program to be relevant, and 97.3% reported applying the skills they acquired. Additionally, 58.6% rated the course content as very good, while 21.6% rated it as excellent. Teachers highlighted several benefits of the PD program, including improved content knowledge and PCK, lesson planning, reflection writing, applying UDL principles and inclusive pedagogies, addressing students' misconceptions, and integrating ICT tools. However, participants also faced several challenges, such as time constraints, heavy academic loads, video recording and peer-review requirements, the extensive course content, and technical difficulties.

Conclusion

The practice-based PD program for secondary STEM teachers in Bhutan demonstrated significant success in enhancing teachers' KAP. With high levels of relevance and application reported by participants, the program proved effective in improving content knowledge, pedagogical skills, and the integration of UDL principles for inclusive classroom practices. Despite some challenges such as time constraints and technical difficulties, the PD model's focus on reflective learning and practical application showed promise for long-term improvement in classroom teaching. This success suggests a strong potential for expanding practice-based PD programs using OERs in Bhutan.

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Constructive Pedagogy and Student Engagement: A Study of the Grade 3 'Small Science' Curriculum

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This study focuses on the constructive pedagogy of the grade 3 'Small Science' curriculum, designed at the Homi Bhabha Centre for Science Education (HBCSE) in the mid-1990s, and its alignment with India's National Education Policy 2020 (NEP2020). This curriculum emphasises hands-on activities and critical thinking, aiming to improve student engagement and understanding. A pre-post test conducted with 120 students in Thane, India, showed improvement in students' learning outcomes, hinting at the effectiveness of this approach. Additionally, interviews with science teachers highlighted gaps in current practices and explored how this curriculum can be adapted to better support modern education. The findings suggest that constructive pedagogy remains a valuable tool in fostering deeper student engagement and comprehension in science education.

Keywords: Constructive Pedagogy, Experiential Learning, Student Engagement

Introduction

Various barriers to pedagogy like large class sizes, resource limitations, outdated curriculums and inflexible teaching methods may lead to gaps in students' learning experiences. This can negatively impact students' performance in standardised tests, reduce classroom engagement, and affect long-term interest in science-related courses. Innovative pedagogy approaches that foster constructivism and active student engagement in the science classroom, address students' alternative conceptions and provide a sociocultural context can improve students' understanding of scientific concepts.

This work outlines the role of the 'Small Science' grade three textbook in equipping the modern educator with activity-based constructivist pedagogy tools to bridge the learning gaps in science classrooms and improve students' learning outcomes. It also aims to identify learning gaps and factors affecting effective learning in the science classroom.

Theoretical Framework

This study's framework draws from the DLIPS project (Chunawala et al., 1996) and HBCSE's 'Small Science' curriculum, emphasising inquiry-based methods to address alternative conceptions. Inspired by Carey's constructivist learning theory (1987), it highlights how children restructure prior knowledge to integrate new concepts. Additionally, diagnostic tests (Treagust, 1998) and teacher perspectives on NEP2020 and classroom challenges (Gomez-Zwiep, 2008) guided the study's design. A workshop for grade three students and teacher interviews were conducted to address the research questions.

Research Questions

- Do active learning methods effectively bridge knowledge gaps?
- How does students' prior knowledge influence learning outcomes in a classroom?
- Do diagnostic tests prove useful to understand and address students' alternative conceptions?
- What challenges do teachers face in implementing active pedagogy in a resource limited classroom?

Methodology

The 'Small Science' grade three textbook was reviewed in conjunction with the science textbooks developed by the Maharashtra State Bureau of Textbook Production and Curriculum Research, Pune (popularly known as the 'Balbharati' textbooks) and the National Council of Educational Research and Training (NCERT). In light of India's NEP2020, a set of interactive classroom sessions on the topic 'Our Body' from the 'Small Science' textbook were planned and executed in a Maharashtra Board school in Thane. Pre- and post-session quizzes were administered to the 120 student participants and feedback was collected. The student responses were analysed to assess the efficacy of constructivist classroom pedagogy in improving students' understanding of scientific concepts.

Games were also used to explore students' understanding of body parts and functions. Additionally, semi-structured interviews and focused group discussions with school teachers were conducted to understand the evolution of science textbooks and pedagogy tools, and their role in improving classroom interaction and learning.

Findings

Students' understanding of structure and function of different parts of the human body showed a significant improvement after the sessions. While students with higher prior knowledge performed better overall, those with lesser prior knowledge showed greater improvement. Oral responses during sessions were more detailed than written ones in both tests.

	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

Fig. 1. Comparison of students' ability to distinguish body parts supported by bones from those that are not. In each group, the left and right bars represent pre- and post-test results, respectively. Bar sections in green indicate the percentage of correct responses, red indicate incorrect responses and gray indicate no response. The table shows the statistical significance of the differences between pre- and post-test results.

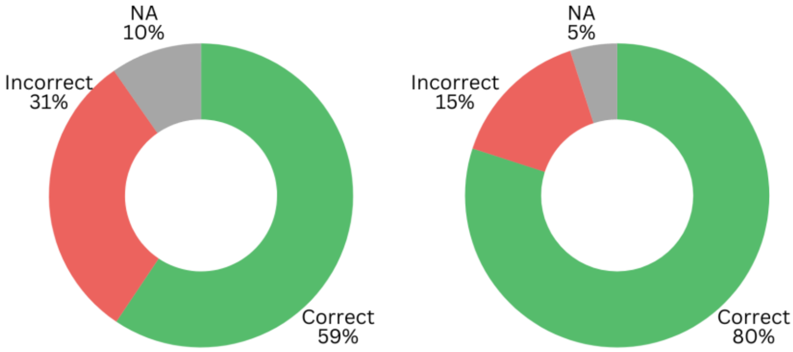

Fig. 2. Comparison of students' differentiation between images of the human hand. The charts on the left and right summarise the responses in the pre- and post-test, respectively. Pie sections in green indicate the percentage of correct responses, red indicate incorrect responses and gray indicate no response. (Z-score: 3.68, p-value: 0.00023)

Teacher interviews highlighted the gaps in current pedagogy practices to teach body parts and the significance of using interactive pedagogy tools like models and demonstrations to enhance student engagement and comprehension. Integrating more practical activities and real-world applications into the curriculum and evolving teaching materials to be more interactive was also a key theme of most responses.

Conclusion

We can conclude that using interactive pedagogy tools in the science classroom can prove to be valuable in improving student interaction and their understanding of body parts.

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Culturally Reproducible STEM Habits and Their Role in Development of Critical Thinking Skills

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Critical thinking skills are interconnected with scientific attitude and form one of the main components of STEM education. The role of collaboration, group engagement, argumentation, etc., is widely known for developing critical thinking skills. However, which cultural cues such as habits, actions, practices are required for developing and shaping critical thinking skills is not widely recognised. In this study, we identify culturally reproducible STEM habits in a group engagement setting and thematically categorise them into different cognitive thinking skills that are shaped by them. The study demonstrates how culturally reproduced conditioning by reinforcement and modeling shapes critical thinking skills.

Keywords: STEM Habits, Critical Thinking Skills, Cultural Reproduction, Social Cognition

Introduction

Researchers define critical thinking as a set of skills which broadly include analysing, evaluating, synthesising, to arrive at interpretations and judgements (Halpern, 1993). However, what actionable tasks need to be done in order to acquire critical thinking and what cultural setting can support its development is hardly defined. Critical thinking is context and subject dependent, it requires knowledge of content and skills to process the information. Therefore, in the context of STEM education, it can be called scientific critical mindedness (Byrne & Johnstone, 1987). Several lines of research point out that most educators focus on content matter rather than instructing techniques to foster critical and analytical thinking in students (Fahim & Eslamdoost, 2014). Critical thinking doesn't develop spontaneously and requires a well-organised learning process and cultural setting (Halpern, 1993). The cultural aspects shaping these skills are often neglected (Grosser & Lombard, 2008). Therefore, the research needs to emphasise what culturally driven actions need to be taken to promote scientific critical mindedness? How do those cultural practices and habits get reproduced and passed on from person to person, group to group and transmitted across communities?

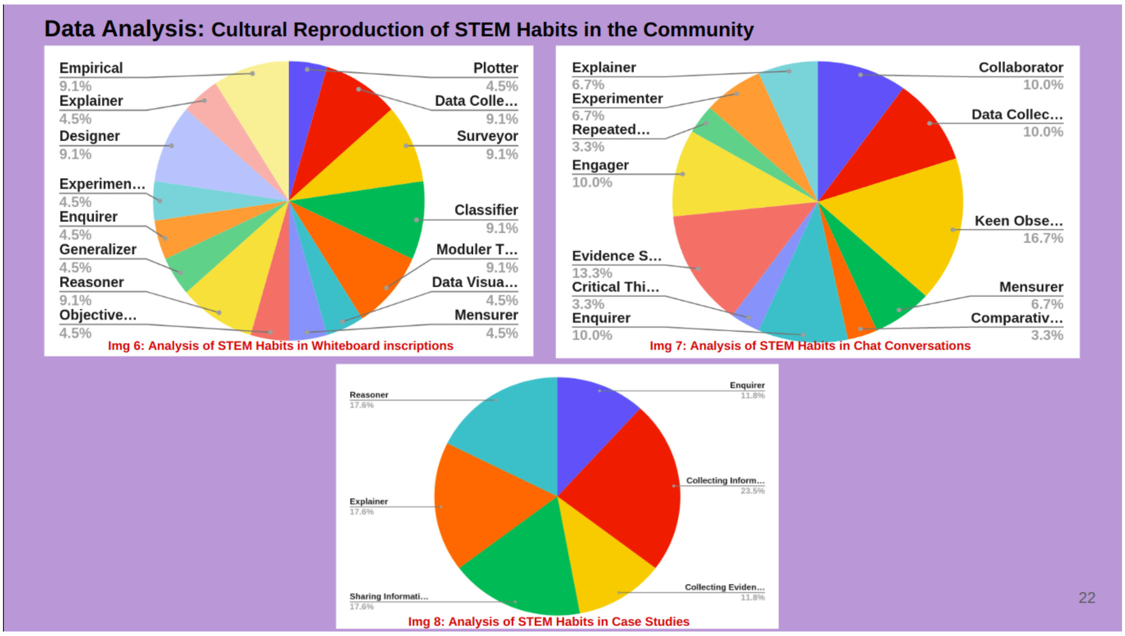
Theoretical Framework

1. We employ cultural theorist Pierre Bourdieu's cultural reproduction theoretical framework to study the occurrence and recurrence of certain customs and habits (STEM habits), in a group of community of practice, and how it is maintained and transmitted across community.
2. We employ Social Cognitive theory (SCT) aligned with Albert Bandura to emphasise the role of culture in development of critical thinking skills.

Methodology

In this study we have created a community of practice named Collaboratively Understanding Biology Education (CUBE), to engage students in scientific practice in Home labs. Students perform science activities, experiments in home conditions and with resources available at home. Students use instant messaging and web-conferencing to interact on a daily basis.

1. We use discourse analysis methodology to analyse the discourses in instant messaging settings (Zastavker et al., 2013). The transcripts of discourses in text and diagrams drawn by students on whiteboard during web-conferencing and blogs are analysed in order to identify which STEM habits are emerging from the interactions among students.
2. We employ thematic analysis methodology to categorise different STEM habits into



themes of critical thinking derived from literature, such as, Logical thinking, Analytical thinking, Creative thinking, Causal thinking and so on.

Fig. 1. Plots showing the cultural reproduction of certain STEM habits

Results and Conclusion

Based on the analysis of episodes of interaction, certain STEM habits are found to be culturally reproducible, for instance, Explainer, Reasoner, Empirical, Classifier, Plotter, Experimenter, etc. The thematic analysis of the episodes based on these STEM habits was performed and they were found to involve different critical thinking skills such as Reflective thinking, Causal thinking, Logical thinking, Analytical thinking, Empirical thinking, Inferential thinking and several other categories of critical thinking. We demonstrate how culture reinforces, shapes reproduction and modeling of STEM habits. The results demonstrate STEM habits help in developing critical thinking skills.

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Addressing Misconceptions in Buoyancy Through Inquiry and Experimentation

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This study addresses persistent misconceptions about buoyancy, a key concept in fluid dynamics, through the development of an inquiry-based learning module as part of the "Vigyan Pratibha" initiative. Misconceptions, such as buoyancy being solely dependent on the weight or volume of the object have been reported in the literature. To address these, a hands-on, inquiry-driven learning module was developed which allows students to recognise multiple physical factors of the object and medium affecting buoyancy. The module, tested iteratively in classrooms emphasises experimentation, scaffolded tasks, and conceptual reflection on buoyancy principles.

Keywords: Buoyancy, Sink and Float, Physics, Misconceptions, Conceptual Change, Vigyan Pratibha, School Education

Introduction and Theoretical Framework

The concept of buoyant force is fundamental to understanding fluid dynamics and has practical implications in fields ranging from engineering to everyday phenomena, such as why objects float or sink. Despite its importance, buoyancy is one of the most misunderstood topics in physics, with persistent misconceptions observed among both students and educators. Misconceptions, such as buoyancy being solely dependent on weight or hollowness, or being considered an "anti-gravity" force, have been well documented in the literature (Buteler & Coleoni, 2000; Kallery, 2000; Unal, 2008). These misunderstandings often stem from oversimplified textbook explanations and a lack of inquiry-based learning opportunities that allow for deep exploration of core scientific principles (Kallery, 2000). In this study, we present the journey of development of the learning module informed by textbook analysis, classroom trials, teacher workshop trials, and preliminary data analysis of students' worksheets.

Key misconceptions about buoyancy, floating, and sinking include the belief that heavy objects sink and the light ones float (Kallery, 2000), that buoyancy exists only when an object is floating (Buteler & Coleoni, 2000), and that volume alone determines whether something floats (Unal, 2008). Some students think air inside an object makes it float and that the liquid's properties don't affect buoyancy (Harrell et al., 2022). Additionally, buoyancy is often misunderstood as an intrinsic property of objects rather than a force from displaced fluid (ibid.).

Textbook Analysis

Initially, we did a critical analysis of the NCERT textbook. The topic of buoyancy is included in the class 9 science textbook at the end of the "Gravitation" chapter. We looked at both the general text on the concept and summative and formative questions in the text. In the NCERT textbook, buoyancy is introduced *"as the upward force exerted by a fluid on an object, which counteracts the object's weight"*. The text explains this through examples like floating corks and sinking nails but lacks opportunities for students to relate in these explanations with buoyancy, density and how they are mutually related. The abrupt transitions between terms like buoyancy and density can lead to confusion without proper elaboration or experimental reinforcement. In another example, the textbook prompts students to think about the nature of the buoyant forces and how it can be explained with Archimedes' principle. This is done without introducing hands-on activity or visual representation which may risk leaving students with an abstract understanding.

Development of the Learning Module

The learning module was developed iteratively, undergoing multiple rounds of discussions, testing and modification based on feedback from classroom visits and teacher workshops. A few highlights of the module are mentioned herewith: Throughout the module, students are encouraged to explore the relationship between buoyancy force, object properties (e.g., weight, volume), and fluid properties (e.g., saltwater vs freshwater). For example, one of the questions in the module asks students to identify the forces acting on an object underwater by drawing diagrams, encouraging them to visualise the forces involved and better connect to the concept. Similarly, Q12 (see Fig. 1) further pushes students to explore the relation between the weights of the objects in the air and underwater, fostering critical thinking about how buoyancy works.

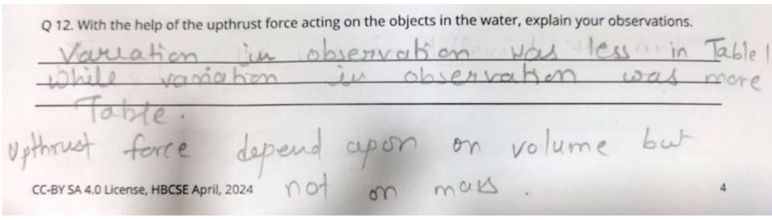
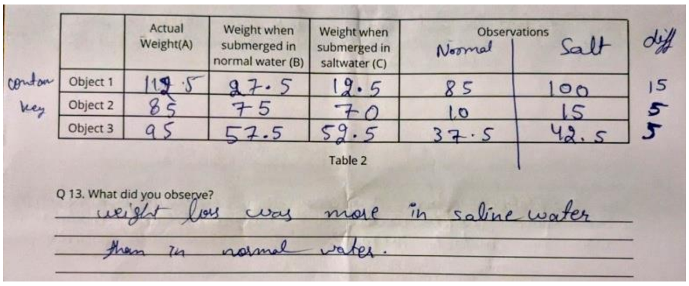


Fig. 1. Example response to question Q.12 from the learning module.

By looking at the response to Q12, we note that students relate their experimental observations (volume -- buoyancy dependency) and comment about the buoyancy force. The learning tasks build progressively, introducing basic concepts [e.g., forces in Task 1 (check the students concept regarding the nature and direction of forces on an object underwater)] before moving to more complex relationships between object properties and buoyancy [e.g., Task 2 (experiment to check the dependency of weight on buoyancy), Task 3 (experiment to check the dependency of volume on buoyancy) & Task 4 (experiment to check the dependency of buoyancy on density of the medium, see Fig. 2)]. Task 2 and 3 engage students in measuring and observing how weight and volume impact buoyancy force. This promotes an exploratory approach where students investigate scientific principles and build a relation between weight/ volume of the object and the buoyancy force. Task 4's investigation into the difference between saltwater and freshwater highlights how students learn through experimentation with real-world examples. This scaffolding allows students with different levels of prior knowledge to gradually build their understanding.



	Actual Weight(A)	Weight when submerged in normal water (B)	Weight when submerged in saltwater (C)	Observations Normal	Salt	diff
Object 1	112.5	27.5	12.5	85	100	15
Object 2	85	75	70	10	15	5
Object 3	95	57.5	52.5	37.5	42.5	5

Table 2

Q 13. What did you observe?
weight loss was more in saline water than in normal water.

Fig. 2. Observation table and follow-up question for Task 4, in this task weight of an object is compared in two mediums of different densities, checking the dependency of buoyancy on the density of the liquid.

As seen by the response in Fig. 2, the student has advanced to address complex scenarios, comparing buoyancy forces in two different situations and predicting where the force is greater. The student is also testing how the density of the fluid affects the buoyancy force on an object. Overall, we feel that the module emphasises student agency, allowing them to draw conclusions from their own experiments.

Future Work

In future work, we aim to expand the analysis to include content from both formal and informal Indian textbooks to understand how concepts of pressure, force, weight, volume, density and buoyancy force are discussed in these resources. Additionally, we will conduct extensive trials of our learning module presented above in selected schools to assess its impact. We will conduct focused group discussions with students to explore their prior knowledge, motivation, and post-intervention learning experiences. Feedback from teachers and administrators will be sought to evaluate the module's feasibility and identify potential limitations.

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Evaluating Project-Based Learning: Effectiveness and Challenges in Middle School Science Education in Bihar

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This study evaluates Project-Based Learning (PBL) in middle school Science (Grades 6-8) in Bihar, India, addressing the challenges of traditional methods in a resource-constrained setting. Grounded in constructivist theories by Piaget and Vygotsky, the research examines how PBL influences student outcomes and engagement. Using a mixed-methods approach with pre- and post-assessments, surveys, interviews, and field observations across 28,989 schools, the study finds that PBL improves teaching practices and student performance. However, issues such as student satisfaction and gender disparities persist. The findings highlight the need for enhanced training and more inclusive projects to maximise PBL's impact.

Keywords: Project Based Learning, PBL, Bihar, Teaching Practices, Inclusive Projects, Training, Pre- and Post-Assessment

Introduction to Project-Based Learning in Bihar's Middle School Science Education

In Bihar, India, a region with diverse educational needs and significant infrastructural challenges, traditional teaching methods often fall short, leading to limited student engagement and understanding. To address these issues, educational strategies combining theoretical learning with practical application are increasingly considered. One such approach is Project-Based Learning (PBL), which integrates hands-on projects with classroom instruction to foster deeper understanding and critical thinking. Research indicates that PBL can significantly enhance student engagement and learning outcomes. Thomas (2000) found that PBL situates learning in real-world contexts, improving comprehension and retention. Bell (2010) emphasised PBL's role in developing essential 21st-century skills, such as problem-solving and collaboration. Additionally, Gulikers et al. (2004) noted that authentic assessment within PBL environments boosts student engagement and achievement. Despite these advantages, PBL's implementation in large-scale, resource-constrained settings like India remains underexplored. This study seeks to address this gap by evaluating PBL's effectiveness and adaptability in middle school Science Education (Grades 6 to 8) in Bihar. By investigating PBL in this context, the study aims to provide insights into its potential to overcome educational challenges and improve outcomes in similar settings.

Theoretical Framework and Research Focus

This study is grounded in constructivist learning theories, particularly those of Piaget (1973) and Vygotsky (1978), which emphasise that effective learning occurs through active engagement and social interaction. PBL aligns with these principles by involving students in real-world problem-solving and collaborative tasks, thereby enhancing their understanding and critical thinking. The central research question of this study is: How does PBL influence student learning outcomes and engagement in science education for middle-grade students (Grades 6 to 8) in government schools in Bihar? This study explores the impact of PBL on these outcomes and examines the challenges of implementing PBL in a large-scale, resource-constrained context. The originality of this research lies in its extensive evaluation of PBL across nearly 28,989 schools, providing insights into its scalability and effectiveness in diverse educational settings.

Research Design and Data Collection Methods

This study uses a mixed-methods approach to evaluate Project-Based Learning (PBL) in Science for Grades 6 to 8 in Bihar's government schools. It includes approximately 28,989 schools and around 54 lakh students. Data collection involves pre and post assessments to measure student knowledge changes, along with surveys and semi-structured interviews with teachers, headmasters, and district officials for qualitative insights. Field observations provide additional context. Quantitative data are analysed statistically, while qualitative data are thematically analysed to assess PBL's effectiveness and challenges.

Key Findings and Insights

The Project-Based Learning (PBL) initiative in Bihar aimed to cover 70% of schools but reached 62%, impacting approximately 3.6 million students. Despite this shortfall, the program achieved high acceptance, with 93% of teachers and 80% of government officials supporting PBL. Training effectiveness was notable, with 78% of targeted teachers trained and 66% passing the PBL quiz. However, student satisfaction was only 54%, highlighting implementation issues. Academic outcomes showed a 1% increase in students surpassing the grade readiness cut-off and a 20% average improvement in scores. Gender disparities emerged, with boys outperforming girls, indicating a need for more inclusive PBL topics. Key lessons include the importance of early field visits for relevant lesson planning, government involvement in content co-creation fostering ownership, and the necessity for consistent training and follow-up to address challenges. The initiative also highlighted the need for targeted strategies to address gender gaps in participation and performance.

Conclusion and Future Directions

The Project-Based Learning (PBL) initiative in Bihar has effectively introduced a new approach to middle school Science education, boosting teacher engagement and student feedback. Although the program reached 62% of schools and faced some challenges, it has led to improvements in teaching practices and academic outcomes. Addressing issues such as student satisfaction and gender-based performance disparities is essential. Future efforts should focus on enhancing training, creating more inclusive projects, and providing consistent support to maximise PBL's benefits in resource-constrained settings.

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Status of Astronomy Education in India: A Baseline Survey

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We present the results of a nationwide baseline survey assessing the status of astronomy education among secondary school students in India. Administered across 10 states and involving over 2,000 students from diverse backgrounds, the survey explored various aspects of astronomy education. Despite a strong interest in astronomy among students, the findings reveal significant gaps in their understanding of fundamental concepts, including celestial sizes, distances, and lunar phases. Additionally, substantial disparities in performance were observed across states. The insights gained offer important implications for comparing state-level teaching standards and guiding the development of a more effective national astronomy curriculum.

Keywords: Public Survey, Astronomy Education, Astronomy in Schools

Introduction

Astronomy education at the school level is uniquely valuable, offering students a broader perspective through its vast spatial and temporal scales while demonstrating the interdisciplinary nature of science, and above all it can inspire greater engagement with science in general. However, in India, this potential remains largely underutilised, as astronomy is often inadequately integrated into school curricula. To improve astronomy education in schools, we need to first evaluate the current status of astronomy education, then identify the areas to improve upon and eventually build a better curriculum. In this project, we are working on the first step, and to that end, we have conducted a baseline survey to investigate student perceptions about various facets of astronomy education. Over the years, several studies (Slater, 2015; Bailey, 2009) have been conducted to investigate the astronomy knowledge of students, however, most of the efforts in Astronomy Education Research (AER) have targeted either undergraduate students or early education (K-4). The few surveys done with high school students are either based on specific narrow topics (concept inventories or CI) or country-specific (Sadler et al., 2010). The field of AER is still at a nascent stage in our country and no such survey has been done before in India. Thus, such a survey can lay important groundwork for further AER research here.

Theoretical Framework and Methodology

Our survey aims to capture a broad range of educational settings, encompassing urban, semi-urban, and rural areas, as well as schools with diverse curriculum boards and mediums of instruction. Survey requests were disseminated to numerous collaborators across the country, ultimately yielding complete responses from ten states that constitute our sample. Within each state, we ensured the inclusion of at least one urban and one rural school to maintain representational diversity.

The survey instrument consists of 16 questions, and they can be divided into five sections: astronomy in the curriculum, general astronomy knowledge, cultural connection, exposure to astronomy, and further interest. The initial survey questions were developed through extensive discussions with teachers, students, outreach professionals, and education researchers. Before the nationwide rollout, a pilot study in two Pune schools informed revisions to improve survey effectiveness. Scientific jargon was minimised, and necessary terms were either defined or translated in parentheses (e.g., "full/new moon," "horoscope"). Questions were also structured to focus on single concepts to reduce ambiguity in responses.

Research Questions

In this talk, we will focus on the general astronomy knowledge part and specifically on these research questions: Do students know basic astronomy concepts? Are there differences in their performances between the different states of India?

Findings

Our findings indicate that a substantial proportion of students (82%) express a general interest in astronomy. However, many exhibit difficulties with basic astronomical concepts, such as distance scales, mass scales, and lunar phases. When asked to "Arrange the Sun, Moon, Stars, and Neptune from closest to farthest (from Earth)," only 35% of the 2,038 students responded correctly. Performance across the ten surveyed states varied significantly (Figure 1), from 15.9% in Jammu & Kashmir to 76.7% in West Bengal, with a median state performance of 31.2%. Another question required students to arrange "Jupiter, Moon, Earth, and Sun" from smallest to largest. Although overall performance was slightly better than for the distance question, state-level results ranged from 58% (Maharashtra) to 91.9% (West Bengal), with a median of 70.5% (Figure 1). In a third task, students were asked to select the correct image (from nine options) for various moon phases (New Moon, Day 2, Day 8, Day 11, Full Moon). Median correct identification rates (Fig. 1.) were approximately 84% for the New Moon and 95% for the Full Moon, but much lower for Days 2, 8, and 11 (around 30%), with considerable variation between states. Only 5.6% of students, on average, correctly identified all moon phases. This extremely low percentage was consistent across states, with minimal variation.

Conclusion

These findings demonstrate that while students generally find astronomy engaging, fundamental concepts remain poorly understood, with significant disparities in comprehension across different states. The study’s insights offer valuable implications for evaluating and improving astronomy education standards nationwide.

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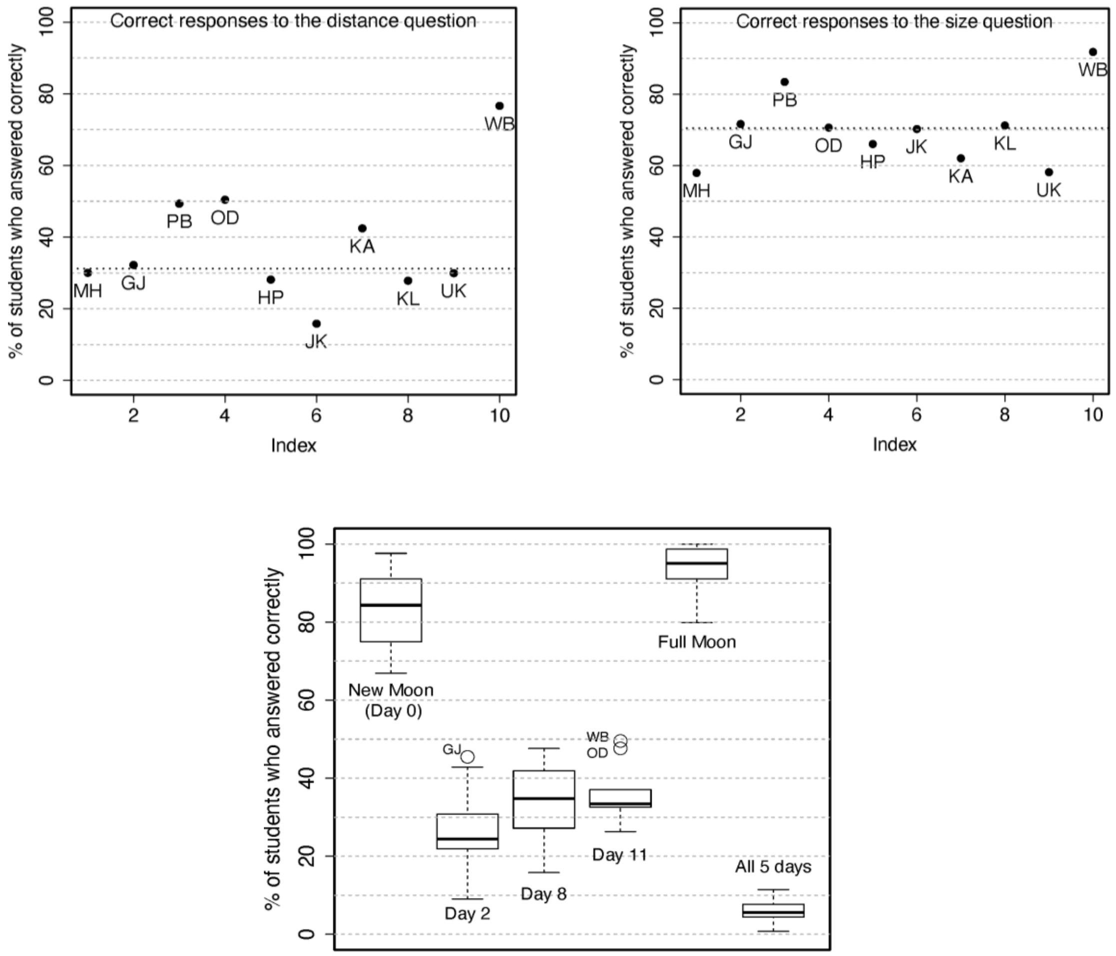

Fig. 1. Top left: Percentage of students who correctly answered the distance related question (arrange Sun, Moon, Stars, and Neptune in order of increasing distance from the earth) in different states. The black dotted line shows the median value (31.2%). Top right: Same as previous but for the size-related question where students are asked to arrange Jupiter, Moon Earth, and Sun in order of size. Below: The plot below shows a box plot of % of students who identified the correct moon images (from 9 given images) across different States. We show the distribution of correct % for images of New Moon (Day 0), Day 2, Day 8, Day 11 and Full Moon Day. The last box plot shows distribution of % of students who identified all these five phases correctly.

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Not So 'Mechanical': Learnings and Insights from High School Science Teacher Workshops on Mechanics

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Drawing from our collective experiences of conducting workshop sessions on Newtonian mechanics for high school teachers, we outline learnings and insights regarding the processes as well as the content and approaches that need to be adopted to navigate the space of creating a conceptual engagement with this particularly tricky subject matter.

Keywords: Mechanics, In-service Teacher Education, Teacher Workshops, High School Physics

Efforts to Work With High School Science Teachers on Mechanics

While introducing canonical physics at the high school level one has to grapple with the matter of helping students (and teachers) engage with the nuanced reasoning which is needed to make sense of the often-abstract notions/concepts involved and the interrelations between the same. As teacher educators, we have long felt the need to create tools and materials to help learners find their way through the subject matter of Newtonian physics and related concepts such as energy. Over several large-scale residential workshops for teachers over the years, we, along with our extended community of teacher educators have had the opportunity to attempt and witness multiple approaches to introduce and develop an understanding of mechanics starting from describing motion to kinematics to inertia and then to Newton's second law and energy. The mode of teaching-learning in such workshops has been close to a broadly social constructivist variety in which teachers work in small groups doing short experiments and/or discussing their ideas about certain observations and concepts which are then collated by the facilitators in whole-class discussions. Most of these approaches have evolved through iterative processes of trial, feedback, reflection and improvement.

Insights and Experiences from Teacher Workshops

We have invariably observed that the overall results from the literature on conceptual change/misconceptions/alternative conceptions/folk conceptions (say, Driver et al., 2014) always hold when questions based on sources such as the FCI (Hestenes et al., 1992) and its derivatives are posed to teachers. We have also observed teachers who possess advanced degrees in science struggling with such fundamental and foundational ideas during workshop sessions. However, merely knowing about the existence of these conceptions itself does not suggest an obvious way to address the same. From our experiences thus far, we are able to claim that an admixture of bespoke and varied approaches that include demonstrations, thought experiments, analysis of experimental data, conventional chalk and talk, drawing from ideas from the history of science, etc. seems to allow learners to engage better with the specific mechanics subject matter at hand. However, we have also realised that building a satisfactory understanding happens to be a relatively slow process - e.g. a sequence of, say, five to six sessions is needed just to reach the idea of inertia starting from a quantitative description of motion. Given such challenges, over the years, we have increasingly come to a conclusion that subject matter as richly complex as mechanics requires a careful pedagogical treatment at the high school level. Even so, the responses of participants over iterations of workshop sessions (as evidenced by their conceptual articulation) and feedback from our fellow teacher educators/facilitators have helped us to further refine and improve these efforts. We wish to share experiences and insights from these attempts to construct sequences of workshop sessions to help teachers develop a conceptual understanding of mechanics at the high school level.

Note: The sessions in different workshops were tailored around content from chapters of the NCERT and relevant state board science textbooks from middle and high school. This spanned mechanics topics from description of motion to Newton's laws and energy.

To discuss the points mentioned above, we draw from the material developed, our respective notes and video recordings from sessions in teacher workshops conducted over the years. Wherever video recordings are available, verbal consent had been obtained from the workshop participants after explaining the intended use of the recordings to them.

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Enhancing Learning in UG Chemistry Laboratories: An Exploration of a Few Alternative Pedagogical Approaches in Indian Context

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This work focuses on some of the alternative pedagogical approaches aimed to enhance the teaching-learning process in the undergraduate chemistry laboratory, specifically in the state colleges affiliated to the university system in India. Some of the approaches explored here are (a) Pre-lab and post-lab components; (b) use of mini-projects mode and (c) presenting opportunities to design an experimental procedure for a given specific experimental goal and then implement the same. The different approaches have been tried during various teachers' and students' camps as part of the National Initiative on Undergraduate Science (NIUS) programme in chemistry.

Keywords: Undergraduate, Laboratory, Alternative Pedagogy, Chemistry, Experiment

Introduction

In chemistry laboratory components (that is, lab courses and projects) of undergraduate curricula, especially in state colleges affiliated to university systems, students often follow predefined procedures in a rather rigid manner. Such educational experiences lack engagement and limit opportunities for deeper cognitive processes such as decision making, problem solving, and reflective thinking. As part of the National Initiative on Undergraduate Science (NIUS) programme in chemistry, we have been trying to explore some of the alternative pedagogical approaches that can be incorporated to enhance the teaching-learning process in the UG chemistry laboratory curricula.

Some of the approaches that are explored by us are: (a) Pre-lab and post-lab components; (b) use of mini-projects mode and (c) presenting opportunities to design an experimental procedure for a given specific experimental goal and then implement the same.

Methodology

In the Pre-lab – Lab – Post-lab framework, we design pre-lab questions to bring students' attention to the broader context of the experiments, to prepare them for observing the relevant changes in the reaction system during the lab work and enhancing their insights about the procedure and procedural steps. Often students are expected to make careful observations of the system. During the lab, students conduct experiments, where they follow procedural protocols. During the post-lab, students analyse and reflect on the data, and draw conclusions, through guided questions designed to promote critical thinking about the experiments.

The mini-project approach consists of multiple tasks/components that may involve different concepts related to one central theme. These sub-parts of mini-project are investigatory in nature and are structured as open-ended tasks. Students can reflect on the procedure. These tasks are linked to one another and often they provide opportunities to explore the domain where students take more ownership to the lab work. Mini-projects within the laboratory course framework can help in developing deeper engagement of students with the content and allow students to explore scientific questions in a more independent and creative manner. Such an approach can help students to build a broader understanding of the domain under investigation.

Designing of an experiment is an under-emphasised pedagogical method of learning in chemistry laboratory settings, especially in Indian context. Allowing students to design their experiments with certain given constraints, helps them to develop critical scientific skills such as hypothesis formulation, variable manipulation, and decision-making, moving beyond the simple acquisition of correct results. By prioritising experimental design, as per the chemistry education studies, learners' focus is shifted to developing critical thinking and innovation rather than following instructions mechanically. Such an engagement also empowers students to take ownership of their learning and prepares them for real-world scientific challenges.

Another strategy which we have tried in all these approaches is prompting different student groups to try slight variations in experimental procedure and then collating classroom data at the end, on blackboard or on a digital platform. This presentation of the whole class results with variations in procedures further enhances understanding of the experiment and their results. In all these approaches, the teacher has an important role as a facilitator in guiding the students minimally and yet bringing them to meaningful peer discussions. Such a process encourages peer collaborations in the learning process.

Findings

These approaches have been tried with undergraduate students during NIUS chemistry camps. The students are asked to present their experimental work and the learnings from the experiments in the form of a hand-made poster/ oral presentation. Based on students' written responses in the experimental worksheets and their group presentations, we can infer that these approaches have facilitated students' understanding of chemistry concepts and helped them connect the concepts to experimental procedures. We also conduct NIUS teacher camps both at HBCSE and outside HBCSE in regular colleges set up where we have primarily conducted discussions about pre-lab – lab – post-lab approach with the teacher community. The feedback from teachers is encouraging.

Conclusion

The current work elaborates all the above tried approaches through experimental examples along with students' feedback. The poster will present details about such camps along with the feedback of teachers. Our exploratory work indicates that these alternative approaches are feasible and can be adapted in UG colleges' chemistry labs in Indian context, especially when colleges are getting academic autonomy.

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Community of Practice Focused Teacher Education Programme for UG Educators: Building Capacity in Using Inquiry-Based, Active Learning, and Assessment-Centred Strategies for Classrooms and Labs

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In the current paper, we present a reflective commentary on designing and delivering a UG teacher education programme, the Maharashtra State Development of Educators and Enhancement in Delivery (MS-DEED) focused on capacity building of teachers of science and mathematics courses in the state of Maharashtra. The programme, focusing on inquiry-based, active learning and formative assessment-centred strategies for instruction, also incorporated designing elements that helped the participants in the implementation of these strategies in their classroom. The paper discusses the nature of these design elements and interventions, along with the participant perceptions regarding the feasibility of implementation of these strategies and possible challenges in their classroom settings, making active learning pedagogies more accessible to UG educators.

Keywords: UG Teacher Community, Inquiry-based, Active Learning, Capacity Building

Introduction

Undergraduate (UG) education in India largely relies on traditional, teacher-centred methods, with limited emphasis on learner-centred experiences, as highlighted by the National Education Policy (NEP) 2020. Unlike school educators, UG teachers lack formal training in pedagogy, and most institutions offer minimal support for developing teaching practices. This gap prevents the adoption of evidence-based, innovative teaching approaches, perpetuating conventional methods and limiting effective learning. While NEP 2020-inspired courses are emerging, transforming UG classrooms through teacher training remains a challenge. To address this, we developed a need-based programme aligned with NEP 2020, emphasising a 'Community of Practice' approach to empower UG educators.

Framework and Designing of the Programme

Our presentation reflects on the conceptual design, implementation and evolution of a teacher capacity-building programme for undergraduate educators, teaching science and mathematics courses for the Bachelor of Science degree in the state of Maharashtra. It is a two-tier model consisting of two phases/levels. Level 1 of this programme includes 25-30 hours of in-person training aiming to sensitise the participant teachers with newer student-centric pedagogies. Select participants from the Level 1 cohort join the 100-hour intensive residential in-person for

Level 2 training, focused on strengthening their understanding of disciplinary pedagogical content knowledge and delivery. The primary objective of the programme was to both sensitise and equip the teachers in the following areas through hands-on-minds-on sessions:

- Inquiry-Based Active Learning strategies (Freeman et al., 2014)
- Purpose of Assessment & Formative Assessment Methods (Boud & Falchikov, 2006)
- Outcome-Based Education (Biggs, 2014)
- Group work for effective engagement (Burke, 2011)

The program, themed "For the Teachers, By the Teachers," emphasised practical and implementable pedagogies for participants' teaching contexts. It was designed considering factors like engagement modes, participants' backgrounds, prior training, student demographics, infrastructure, and administrative support. Objectives were addressed through active sessions on inquiry-based teaching, learning outcomes, formative assessments, and subject-specific hands-on labs. Teachers engaged as learners in collaborative, active learning experiences.

Research Questions

This paper examines key design elements of a teacher development programme for science and mathematics educators, focusing on supporting effective post-training implementation. It also analyses challenges and barriers teachers face in applying these strategies in classrooms. Key questions we aimed to address are:

- What do UG educators perceive about the feasibility of implementing inquiry-based and active learning strategies, and which strategies do they consider most suitable?
- How effective were the interventions in equipping participants to implement these strategies in their classrooms?
- What challenges do participants foresee in adopting these strategies in conventional classroom settings?
- What role does a 'Community of Practice' play in sustaining and scaling the implementation of evidence-based teaching methods?

Methodology

Data on participants' initial responses to implementing active learning pedagogies was collected through a Google Forms survey (within a week of the workshop), discussions, and interviews. Thematic analysis by two researchers validated findings from ~630 responses across 11 Level 1 workshops in Maharashtra, examining teachers' acceptance, challenges, and perceptions. A follow-up survey (3 months to 1.5 years later) explored the actual implementation of learned practices, identifying challenges and motivational factors. Focused group discussions with selected participants provided deeper insights into their experiences. Multiple structural elements and strategies were introduced in the design of the sessions to enhance the implementability of the session content (elaborated in Fig.1) Additionally, the MS-DEED team tailored training to participants' needs, emphasising small, manageable implementation steps.

Response Data of Teacher Participants and Analysis

UG educators were surveyed on the feasibility of implementing workshop pedagogies, with over 95% finding them practical and intending to apply them within a week. About half planned to use inquiry-based or active learning methods more than twice per semester, while others preferred 1-2 uses. Participants shared integration strategies and highlighted institutional barriers, that are analysed thematically to inform future programs.

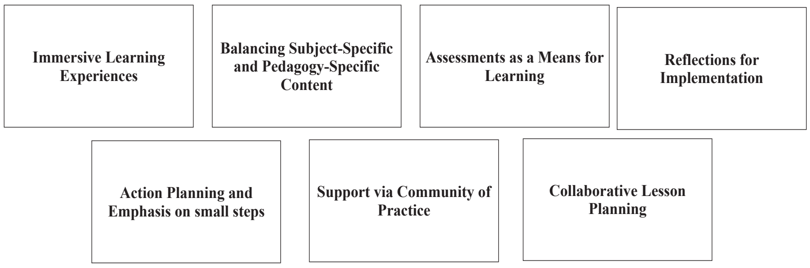

Fig. 1. Multiple programme elements introduced to enhance the implementability.

Conclusion

Key factors influencing successful implementation included the active participation of teachers as learners during the workshop, interactive and activity-based sessions, tailor made content and delivery, reflective practices. Though commonly cited barriers included time constraints and large class sizes, the majority of teachers reported enhancement in classroom engagement and no significant challenges in implementing active learning strategies post training.

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Socially Responsible Science Education (SRSE) in Rural Science Classrooms: Challenges, Practices and Teacher Development

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India, with its vast population and diverse cultural and social backgrounds, presents a unique set of challenges when it comes to science education. In this paper, researcher explore the possibilities of Socially Responsible Science Education (SRSE) in rural secondary schools of eastern districts of Uttar Pradesh. The researcher adopts Socio-scientific issues (SSIs) for situating SRSE. The study employs critical qualitative inquiry to investigate teachers' practices, perspective on the degree to which science curricula are aligned with SSI-based teaching in rural context, issues & challenges in promoting SRSE. Results reveal disparities in teacher training, lack of resources and offered suggestions for professional development of science teachers in rural areas. This research is an attempt to contribute to this discussion surrounding science teaching and learning with social and ethical responsibility.

Keywords: Science education, Socially Responsible Science Education (SRSE), Rural Context, Socio-Scientific Issues (SSIs)

Introduction

In India, equity and accessibility are pressing concerns in the education system, particularly in the realm of science education. India, with its vast population and diverse cultural and social backgrounds, presents a unique set of challenges when it comes to science education. Particularly in rural areas, there are several socio-scientific concerns that need to be addressed. The curriculum is often designed in a way that does not account for the socio-cultural context in which the students live. Bencze et al. (2020), emphasised the importance of "science-in-context" approaches in socially responsible science education, which involve integrating science with social, cultural, environmental and ethical issues. Fuchs & Tan, (2022) analysed four frameworks, including SSIs based teaching, which can support socially responsible science education where teachers agreed that frameworks benefit student learning by providing a context for students to use and learn science.

Theoretical Framework

Socially responsible science education is an approach to science education that focuses on promoting equity, inclusivity, and sustainability. Ensuring equity and access to science education for all students and promoting environmental stewardship and sustainability are important aspects of socially responsible science education. Fusch (2023) describes SRSE as, "*learners are guided to view themselves as members of society who would employ their understanding of scientific concepts and processes to issues that affect their lives, culture, and the environment, as a means of caring for themselves, others, and their community*". The use of SSIs based learning, as outlined in Allchin (2013) and Bencze (2017), provides a pedagogical framework for engaging students in real-world issues. This approach encourages students to collaborate, communicate, and think critically about the ways in which science can impact society and the environment. Resnik & Elliott (2016) and Kourany (2013), discusses the concept of socially responsible science education and the importance of interdisciplinary, ethical, and critical perspectives in science education, and encourage students to engage in informed decision-making and responsible scientific practice. In this context, the researcher aims to explore the SRSE in addressing SSIs. The study seeks to answer questions such as how SRSE is defined and understood in a rural context? and what gaps exist in the current teacher education programs that may hinder in implementing SRSE?

Method and Findings

The researcher collected data through semi-structured interviews of 10 teachers from two eastern districts of Uttar Pradesh. The interviews addressed the teachers' opinions about both what use social, ethical and environmental issues have in science education and their own efforts to provide some instructional experiences within their classrooms. Key challenges and patterns of teachers' understanding and practices were identified from the data, and thematic coding was employed to analyse data.

Data, Sampling and sample selection criteria: Data collected from two eastern districts (Pratapgarh & Prayagraj) of Uttar Pradesh. Purposive sampling opted for the selection of teachers teaching science* up to secondary level (9^{th} -12^{th} as per NEP 2020) in government schools (GHS-Government High School, GIC- Government Inter College and GGIC- Government Girls Inter College). Total 10 teachers participated in this research i.e. five male and female teachers. The criteria for sample selection include subject specialisation, familiarity with the socio-cultural dynamics of rural students, and willingness to engage in discussions on SSIs and prior exposure to professional development programs in science education, if any.

Context: Schools selected for the study were located in rural areas of the two districts, catering predominantly to underserved communities. The choice of districts reflects the diversity of rural challenges within a broader geographic region. These schools faced challenges such as inadequate infrastructure and teaching learning resources as already reported in the preliminary study (Kajal & Singh, 2022). The medium of instruction was Hindi.

***Tool & validation*:** Semi-structured interviews questions were developed and the tool was validated by experts (teacher educators from central universities of India).

Procedure: Step-1, Formulation of SSIs relevant to rural areas aligned with content related to the syllabus at the secondary level. 1) Menstrual health & hygiene; 2) Menstrual waste disposal; 3) Reproductive health rights (RHR): 4) Food & Agriculture; 5) Manual Scavenging. Step-2, Discussion with teachers on listed SSIs, identification of controversial understanding within the issues, validation of SSIs with experts.

Key findings: Teachers primarily found it difficult to incorporate SSIs into their science teaching practices. Almost all the teachers lack clarity on linking social-scientific concerns while teaching science as per the responses. However, all the teachers agreed that social, ethical and responsibilities should be discussed in science education. Menstrual health, sanitary waste disposal and RHR were among the topics seen as taboo subjects, which either evoked strong emotions or were dismissed because they were considered irrelevant, sensitive and controversial issues, leading to hesitation in classroom discussions. In addition, several teachers refrained from or felt uncomfortable tackling SSIs, citing community backlash or administrative repercussions.

Major challenges: 1) Teachers were unprepared to handle complex socio-scientific topics; 2) Lack of training related to updated pedagogical techniques for in-service teachers; 3) cultural sensitivity and taboos; 4) pressure of syllabus completion; and v) exam-centric approach to education.

Discussion and Conclusion

SSIs can create opportunities for SRSE in rural settings, by providing students with a contextual framework to explore real-world or issues relevant in their local context, thereby making science teaching and learning more meaningful for the learners. This study used semi-structured interviews to understand rural science teacher's perception towards SRSE and integration of socio-scientific issues (SSIs) into their teaching. In discussions, participants expressed a high level of discomfort in speaking about culturally sensitive topics — including menstrual health, waste disposal and RHR. From understanding these insights, the instructional materials for two issues were prepared. These issues put a lot of focus on scientific approach, socio-culture considerations and ethics so as to fit the local environment. After this, teachers had an engaged conversation on these issues, some sharing their criticism and suggestions. For example, one of the participants said, 'It would be easier if these issues are mentioned in textbook, then only we can discuss.' Another mentioned that, "students are curious and often ask questions, but it's difficult to balance openness with societal norms". However, all the teachers agreed and showed their interest that social, ethical and environmental responsibilities should be discussed in science education. Teachers reported that teacher development programs, as they exist today, do not have modules on providing guidance on how teachers are supposed to address controversial topics in their real-world or local context to make science teaching and learning more meaningful for the learners. The procedure emphasised how critical it is to avail concentrated professional assistance such as creation of resources and awareness to the local socio-cultural practices and norms, to achieve the effective implementation of society science integration in science teaching. The findings show a complex picture of barriers, including poor teacher training in the region, limited resources, and deep-seated social taboos. Schools also need to be flexible and supportive places where controversial topics can be discussed. This research recognises limitations that include small sample size and suggest that future studies assess the long-term impact of these interventions.

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Strand 2

Cognitive and Affective Studies in STEM Education

Modelling in STME

Knowledge representation

Affective aspects of learning

Problem solving, learning and reasoning

Language and learning

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Making a Case for Representing Science Explanations as Flow Charts for Revealing Their Logical Flow Structure

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Science explanations are conventionally written in paragraph format. This paper argues that a Flow Chart Format (FCF) can be an alternative yet complementary format worth investigating, as FCF can reveal the logical flow of explanations in a visual form, similar to how flowcharts are used for representing computer program algorithms. A novel framework (PRESTO) developed for presenting explanations, proofs, derivations in FCF is also proposed. Its preliminary application in classroom contexts is described, focusing on comprehension and assessment. Numerous examples will be presented to demonstrate that explanations (simple and complex) can indeed be presented in the form of flow charts.

Keywords: Explanation, Flow Chart, Formative Feedback, Assessment, Premise, Categorisation

Introduction

Often the attempt by (some) students to explain natural phenomena verbally or as written answers in their exams or in class seems inadequate/ incorrect, simply for the reason that a chain like logical reasoning is absent (de Andrade et al., 2019), even though the explanation may contain at least some of the principles/concepts, premises or key words (as expected in a mark scheme). In such cases it becomes difficult to evaluate its correctness. Thus, the need for creating an alternate format other than a text-only format, was motivated by the challenge the author faced as a Physics teacher while assessing explanation answers.

If we consider previous research in the context of science explanations, much of it has focused on either analysing explanations written by students (de Andrade et al., 2019; Wagner & Priemer, 2023; Yeo & Gilbert, 2022) or those that propose frameworks that could help students craft their explanations better (Tang, 2016). In the approach so far, it is observed that the studies focus on student explanations that are mostly written in *paragraph* format. Even though in some of the literature we can see that chain like or flowchart formats have been used or introduced (Tang, 2016; Ariely et al., 2024), they do not propose or advocate the use of a Flow-Chart Format (FCF) by *students* to construct their (science) explanations. Thus, to address this gap, this paper proposes a novel approach wherein students (including teachers and science communicators) can use a FCF for communicating their science explanations in a (text + visual) form, following a basic familiarisation/ orientation.

Flow Chart Format (FCF): Motivation, Research Questions, Proposed Solution

Motivation: Flow chart is one kind of a graphic organiser format which is widely used for presenting, for example, computer program algorithms. An FCF has also been proposed for presenting general arguments (Toulmin, 1958) and for geometry proofs (Cirillo & Herbst, 2012), (Anwar, Mali & Goedhart, 2021). Considering these use cases and the well-known advantages of graphic organisers that aid visual learning (Condidorio, 2010), it is a natural and logical next step to make use of this format for presenting *Science Explanations*, including- Mathematical Proofs, Numerical Problems, Derivations etc. All such solutions have a converging FCF structure, different from that of mind map or concept map. Moreover, now with software like *draw.io* or *miro* one can create such diagrams easily, whereas the same task would have been cumbersome a few decades ago.

Research Question (RQ) and Problem Statement (PS)

- RQ: Is it possible to craft science explanations in the format of a flowchart?
- PS: To develop an FCF framework for convenient use by students and teachers.

PRESTO Framework (Premises-REasoning-STeps-Outcome)

This framework was iteratively developed starting from an initial basic format (Karve, 2021), or (Tang, 2016), by molding existing (expert) explanations into an FC format. Sources of solutions were textbooks, videos, answer schemes and research papers. This methodology led to the present PRESTO framework (Fig.1) that consists of a rational categorisation of premises and processes blocks (‘vocabulary’), and defining their connections (‘grammar’). Owing to these categories and their corresponding colours, each block ‘acquires a certain character’, similar to the way different chess pieces have different capabilities. Colour coding these premises in the FCF solutions can provide a quick visual information about the types of premises, processes and steps involved and their location within the FC diagram. Additionally, each block can contain multimodal elements like diagrams, graphs, mathematical expressions. A large collection of examples (as in Fig.1) can help in orientation of students and teachers to the format, and thus enabling its adoption/ application to other such solutions.

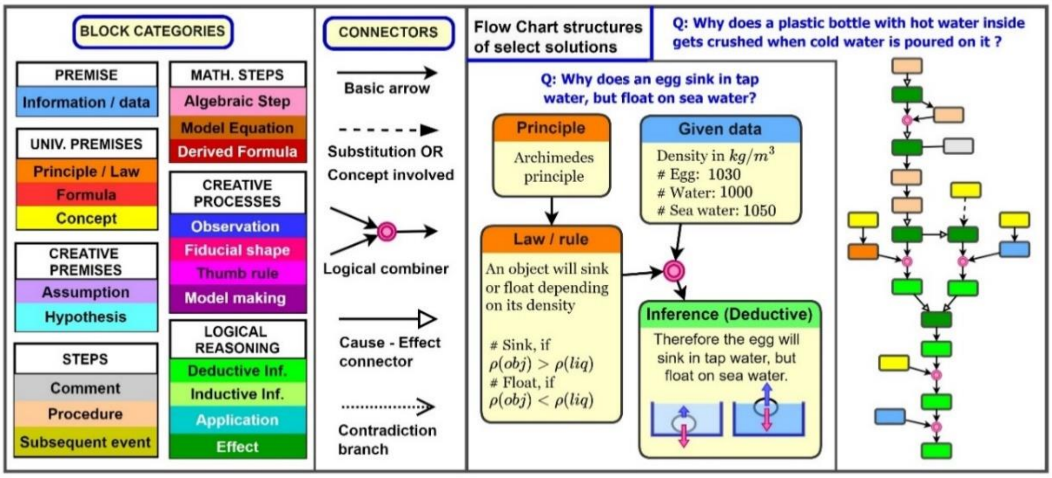

Fig. 1. The blocks and connectors used in PRESTO Format, and sample solutions presented as flow charts.

Classroom Experience

In Physics classes of school level (8^{th} to 12^{th}) these kinds of diagrams were shown to students on a projector to aid their *comprehension* of explanation answers. Such diagrams (as shown in Fig.1) visually revealed the typical components like principles (through color coding), and the logical structure of an explanation. It was encouraging to know that some students actually used this format to write their derivation answers, and some others expressed that: ‘it helped them understand how different concepts came together for longer answers'; 'helped connect the ideas, steps and reasoning'; 'the logical structure became visible' (Karve, 2021).

This format was also used for *formative assessment* for an IBDP (11^{th} grade) class. For an explanation about how an object achieves terminal velocity, a skeletal FCF structure was provided (16 total places) along with some blocks placed in the correct places (in Google Jamboard). The students were then required to place the remaining blocks in their correct places, working in pairs. As a teacher, the author could provide quick feedback, by only having to check the positions of the blocks. This process can easily be automated similar to (Ariely et al., 2024), leading to gamification.

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Using Diagnostic Questions to Analyse Difficulties in Understanding Plant Physiology Among Undergraduate Biology Students

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Plant physiology and cellular respiration are challenging in understanding for undergraduate biology students. Misconceptions in one topic can persist in connected core topics. The conventional assessment does not highlight students' difficulties or misconceptions. The objective of study is to diagnose students' conceptions through a post-test design, wherein students' responses were evaluated using diagnostic questions following plant physiology course. Findings suggest that even though most students provided correct responses on structural aspects of photosynthesis, their difficulties, misconceptions were highlighted during application of core concepts for tracing matter and energy. The study has implications for designing pedagogical intervention at undergraduate biology education.

Keywords: Plant Physiology, Diagnostic Questions, Matter, Energy, Undergraduate Biology Education

Introduction

Plant physiology and cellular respiration are interconnected and core topics to understand how the world functions as an ecosystem. Misconceptions in one topic get carried over to the other topic, resulting in an increasing number of difficulties in the core topics. Not many studies have been conducted in India at undergraduate biology level. The conventional assessment of mid-term and final examination does not cater towards identifying misconceptions. The objective of this study is to diagnose students' conceptions about matter and energy from the plant physiology course using validated diagnostic questions that can help for instructional change and developing pedagogical interventions.

Theoretical Background

Various studies have recorded misconceptions at college and undergraduate level (Amir & Tamir, 1994; Treagust, 1988; Wilson et al., 2006; Wynn et al., 2017). For example, the idea that plants obtain nutrition from the soil that matches everyday experience with plants. Several misconceptions indicate confusion about the roles of the products, reactants, and sunlight in photosynthesis, wherein students think that sunlight contributes to the mass rather than providing energy to the reaction. Students often do not relate to the role of carbon dioxide in plant mass. Most often students think that dark reactions occur in the absence of light. Using Concept Inventories (CI) along with active learning strategies and a scientific teaching approach can be valuable in undergraduate classroom teaching and learning (Parker et al., 2012). CIs enable instructors/teachers to diagnose students' difficulties (D'Avanzo, 2008), are multiple-choice questions scored objectively, such that the wrong responses that serve as distractors have emerged from extensive research, and reflect students' own ideas (Lin & Hu, 2003; Wilson et al., 2006).

Methodology

A post-test study design was conducted with convenience sampling of First Year B.Sc. (Biotechnology) students (n=28, male=8, female=21; age=17-18 years) at a local college in Mumbai (IRB approved). The biology college teacher delivered a semester long course on plant physiology, photosynthesis, chemical reactions, light reaction, Calvin cycle, from their syllabus. Before the course, students were informed of the study about administering CI after the course, and their responses required critical thinking. The CI comprised of 14 test items: Q1-Q6 are about structural aspects, site of photosynthesis, light reaction, Calvin cycle, common with their regular internal examination; Q7-Q10 are about tracing matter; Q11-Q14 are about tracing energy. The Q7-Q14 test items are adopted from a validated questionnaire with written permission (Parker et al., 2012). Students were administered the paper and pencil-based CI task to be completed in one class period of 50 minutes.

Analysis and Findings

In the present study, only two test items representative from each category are discussed. Each test item in CI had one correct response with four-five distractors based on research on students' alternate conceptions. For a question related to Euglena obtaining energy (Fig. 1), only 25% of students mentioned correct response of sugars in chloroplast to make ATP, however, their difficulties also indicated about using ATP made during photosynthesis; or utilising inorganic nutrients from surrounding water to make ATP. For a question related to keeping a potted plant in dark will result in weight loss or weight gain (Fig. 2), only 6% of students indicated correct response. Students think plants will weigh more due to water and soil, and because of the formation of glucose. The common misconception about weight gain is because students think that photosynthesis (an anabolic process) is still occurring, and glucose formation is taking place. However, students are ignoring that in respiration, (catabolic process), the complex organic compounds are converted into simple substances, for example, the breakdown of sugar into carbon dioxide, water results in loss of mass and hence weighs less.

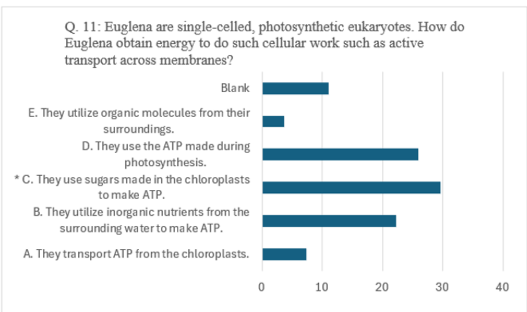

Fig. 1. Graph showing responses about Euglena energy. The correct response is marked *.

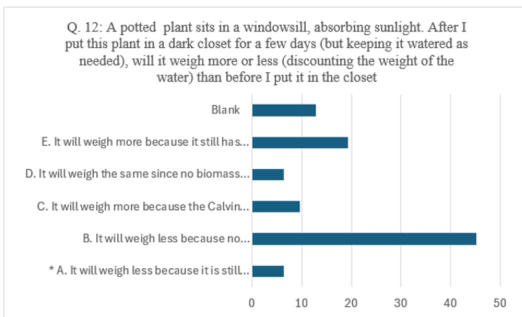

Fig. 2. Graph showing responses on potted plant and and weight. The correct response in marked *

Conclusion

While students identify the conceptions are related to energy transfer, their knowledge on distinction between the two energy processes of photosynthesis and cellular respiration is limited. Although the study has limitation of post-test design only with a smaller sample, these findings can be useful for developing pedagogical interventions at undergraduate biology level.

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Nature of Science (NOS) in Science Curriculum: A Critical Analysis of Secondary Science Textbooks

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The study explores the integration of Nature of Science (NOS) themes within the science textbooks at secondary level. The study adopts and explains different theoretical models for the integration of NOS within the science textbooks and curriculum so as to improve scientific literacy among students. The critical content analysis of the textbooks reveals the presence of a few NOS themes such as, objectivity, experimentation, inquiring, drawing inferences, etc. within the science textbooks, however few themes could not be integrated in the textbooks. The picture of science portrayed by the science textbooks is mostly non-falsifiable and objective. The study has implications for curriculum developers, textbook writers and science teachers.

Keywords**:** Nature of Science (NOS), science curriculum, textbook, scientific literacy

Introduction

Science education and pedagogy of science should include ideas pertaining to the nature of science for a better scientific understanding rather than presenting science as a 'folk knowledge' coming from certain assumptions/beliefs about science (Gilbert, 2015). There has been a huge debate world over for the inclusion of Nature of Science (NOS) components within the school science curriculum. There are different theoretical models that researchers have used to understand and integrate NOS within science curriculum, however, scientists and philosophers of science have always been concerned with the oversimplification and misrepresentation of scientific discoveries, facts, and data. In India, textbooks are considered to be the sole arbiter of knowledge especially when it comes to school science. Therefore, it becomes pertinent to analyze the integration of NOS themes within the science textbook. The primary objective of the present paper is to analyze the science textbooks at secondary level for the integration of various NOS themes within them.

Theoretical Framework

The way in which science is currently being produced in the school science textbooks is inductive in nature rather than as a result of empirical enquiry and often scientist is represented as the only person working in lab which is not true (Gilbert, 2015). The school science curriculum should consider certain discontinuities, irregularities, unsuccessful experiments and falsification of theories rather than presenting scientific knowledge as given facts, theories, and uniform laws. The question that often comes in mind is, what kind of scientific understanding do we aim at through the school science curriculum? Also, how far science textbooks provide a realistic picture about science and nature of science?

Research Questions

The major research questions guiding the present study were:

- Do the present science textbooks integrate NOS themes within their content?
- What kind of inclusion of NOS themes is seen in the science textbooks?
- Which are the major NOS themes that are seen in science textbooks and how do they support scientific understanding among learners?

Methodology

The research method involved critical content analysis of science textbooks (mostly NCERT secondary science textbooks) from a NOS perspective using the CV & FRA frameworks. In order to analyse and explore the integration of NOS themes within the science textbooks, the present paper uses the understanding gathered from two different theoretical frameworks, mainly, the consensus view (CV) on NOS (Abd-El-Khalick & Lederman, 2000; Abd-El-Khalick et al., 2008; Lederman, 1992), and the Family Resemblance Approach (FRA) (Irzik & Nola, 2011) to NOS. These frameworks are broadly used to analyse the science textbooks at secondary level for the integration of NOS and for building authentic scientific understanding among secondary level learners.

Findings

From the analysis of textbook content at the secondary level (refer Table 1), it appears that the textbook does address some themes of NOS, such as, science as empirical, inferential, theory laden and that scientific laws are descriptive statements of relationships between observable phenomena. However, there are many NOS themes that remain unaddressed in the science textbooks such as, science as tentative, creative endeavour, non-linear scientific method, socio-cultural embeddedness of science and values in science.

NOS Themes from Literature (based on CV & FRA frameworks)	**Chapter Title**	**NOS themes present in the chapter**	**Examples from the Science Textbook**
Science as empirical (Abd-El-Khalick et al., 2008, 2017)	Matter in our Surroundings	Theme: Science is empirical • Observation • Inquiry • Experimentation • Scientific reasoning • Drawing inferences • Empirical basis	Some activities in the chapter instil observation, inquiry and help students in learning basic experimental skills. For example, collecting different articles, observing, and identifying their shapes and other properties such as whether they are diffusible, compressible, etc. Some questions in the chapter also help in thinking about the reasons for daily phenomena, like: • What about a rubber band, can it change its shape on stretching? Is it solid? • What about sugar and salt? When kept in different jars these take the shape of the jar. Are they solid? • What about a sponge? It is solid, yet we are able to compress it. Why?

Science as inferential (Abd-El-Khalick et al., 2008, 2017)	The fundamental unit of life	Theme: Science as inferential • Observations • Experimentation • Drawing inferences • Scientific reasoning • Empirical basis	The chapter includes many activities that involve observation, experimentation and drawing inferences, such as, observing cellular structure under the microscope, identifying different types of cells based on their shapes and sizes, osmosis in egg and resins when dipped in different solutions and drawing inferences.

Table 1. Content analysis of NCERT secondary (Grade 9 & 10) science textbook for inclusion of NOS themes

Conclusion

From the analysis of textbook content at the secondary level, it appears that the textbook does address some themes of NOS, such as, science as empirical, inferential, theory laden and that scientific laws are descriptive statements of relationships between observable phenomena. However, there are many NOS themes that remain unaddressed in the science textbooks such as, science as tentative, creative endeavour, non-linear scientific method, socio-cultural embeddedness of science and values in science. The objectivity of science predominates the textbook culture because of which many essential themes of NOS get side-lined. The focus of the textbook is more on theory-building and re-emphasizing the existing laws and theories in science, leaving less scope for creativity and experimentation for the learners which also makes them believe that science is infallible and non-falsifiable which is not true. The study has scope for curriculum developers, textbook writers and science teachers for including NOS themes within science curriculum and pedagogy for building authentic scientific understanding among learners.

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Avenues for Eliciting Proving-Related Processes in Nationalised Middle Grades Mathematics Textbooks of India

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Proving- related processes are foundations of mathematical thinking. Researches all over the world showed that textbooks offer limited opportunities for students to engage in proving-related processes (Bergwall, 2019; Thompson et al, 2010). This study aimed at looking for avenues of proving-related processes in nationalised elementary grade textbooks and the justifications provided in the Introduction section of the chapters. Findings of the study revealed that textbooks provide ample opportunities for reasoning and justification to students but there is dearth of opportunities for conjecturing and exploratory tasks in middle grades. Empirical argument is the preferred mode of argumentation used in textbooks but these arguments do not qualify as valid justification rather work as verification.

Keywords: Proving-related processes, Empirical argumentation, Exploratory tasks

Introduction

Proving is the process of search of 'valid justifications' for a mathematical claim. Although national and international curriculum documents emphasize on proving-related processes to be indispensable component of mathematics curriculum (NCTM Principles and standards for school mathematics, 2000; NCF, 2005, 2023) but global research findings indicates that students lack coherent understanding of proofs (Balacheff, 1998; Martin & Harel, 1989; Chazan, 1993). To dwell into the reasons the nationalized textbooks of elementary grades were analyzed to study how properties were justified in these textbooks and what avenues were provided for students to engage in proving-related processes in the chapters related to Arithmetic.

Theoretical Framework

This study took the standpoint that students' engagement in proving process is elicited by other auxiliary processes. It's not a stand-alone activity but exist in continuity with other processes (Stylianides, 2016; Yeo, 2017). Recognising the importance of this engagement, we propose that to learn 'proof' one must go through these processes which we termed as *proving-related processes* in this research. *By proving-related processes we mean: the processes that cognitively binds the entire process of formation of mathematical claims till the production of their proofs such as patterning, conjecturing, reasoning and justification, argumentation, verification, and generalisation.*

Research Questions

The study aims to address the following research questions:

- What is the nature and extent of the opportunities available in the mathematics textbook of grade 6 to grade 8 to engage students in proving-related processes?
- How textbooks exemplify justification of properties through introductory sections?

Methodology

This study uses a mixed-methods approach, combining both qualitative and quantitative research designs to analyze NCERT elementary grade mathematics textbooks, 2006_{th} edition, taken as sample in this study. Separate analytical frameworks were developed to analyse introductory sections of the chapters and students' exercises, guided by the framework given by Thompson et al (2010) and Stylianides (2016).

- Introductory Section: Introductory section is the part of a chapter which introduces new results and properties. The unit of analysis is 'mathematical statements' that present a mathematical result. Six category codes of justifications were developed using Stylianides (2016) idea of 'mode of argumentation' and Harel (1998) proof scheme. These codes were as follows:

Table 1. Coding scheme for introduction

Mode of arguments	Category	Code Assigned
Argument based on specific examples or concrete manipulation. These are sub-divided in two categories: • Random examples • Usage of examples to highlight a pattern	Empirical	EMP EMP(RE) EMP(PT)
Argument based on generic example-	Generic	G
Argument based on transformations	Transformation	T
Argument based on definition or a property	Deductive	D
Argument based on logical deductions qualifying as proof	Proof	P
No argument is presented or left to the students for justification	No-Justification	NJ

- Student's Exercises: These are the tasks meant for students to perform after the introductory section of the chapter. The unit of analysis for Students' task is the task assigned a separate number or label. Six process codes were developed to categorise the tasks on the basis of goal of the tasks namely, patterning (PT), conjecturing (CJ), reasoning and justification (RJ), specializing (SP), generalisation (GZ) and verification (VF).

The coding was done in two phases. In first phase, justifications presented in the Introductory section of textbooks were coded and in second phase, student's tasks were coded and analysed. The coding procedure was repeated two times with a gap of three months to ensure the reliability of coding.

Findings

Finding of the study revealed that textbooks offer ample opportunities for students to reason and justify the claims which comprises of 71%, 54%, and 54% of the total proving-related opportunities found in grade-6^{th}, 7^{th} and 8^{th} Grade textbooks respectively. But opportunities for conjecturing (~5%), generalizing (~1%) and explorations (~3%) were very less. On the contrary, NCERT textbooks exemplifies conjecturing process, by showcasing formulation of properties through means of observing patterns and examination of examples or non-examples. These claims were predominantly justified by means of empirical argumentation. Out of 152 properties identified, *around 43% of the properties were justified using examples*. An over-exemplification of the usage of examples in the textbook's justification might limit students' understanding of proving as verification and forbid them to appreciate larger goals of proving (Stylianides, 2016).

Conclusion

This study showed that NCERT elementary grade textbooks were potentially effective resource in developing reasoning and justification but there is dearth of opportunities for conjecturing and mathematical explorations. The study also highlights the usage of empirical testing as the dominant mode of argumentation which blurs the lines of proving and verification in the domain of Arithmetic.

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Types of Proofs that Teachers Use While Engaging in an Open Mathematical Exploration

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All secondary mathematics teachers teach proofs in their classroom. But they rarely get an opportunity to think of new proofs, which are different from the ones they teach. To understand the types of proof teachers, use when they want to prove 'new' claims, we analysed assignments submitted by 41 secondary mathematics & science teachers post a virtual mathematics session on teacher capacity-building.

Keywords: Mathematics Education, Proofs, Open Exploration

Introduction

Proofs are central to the discipline of mathematics, but that cannot be said about the role of proofs in school mathematics. A lot of researchers have recommended that proofs should be central to school students' mathematical experiences (Yackel & Hanna, 2003). School textbooks rarely give teachers & students opportunities to 'prove' (Wu, 1996). In secondary mathematics, proof or proving is often looked at as a formal activity isolated from the other mathematical activities done in the school (Stylianides, 2008).

About the Study and the Data

In order to improve the role of proofs in secondary school mathematics, activities which promote situations where teachers and students feel the need to prove and get opportunities to prove the 'new' or 'unknown' results need to be developed. The sets of tasks titled 'Exploring Patterns in Square Numbers' were conducted virtually with secondary mathematics & science teachers with the same objective.

The tasks

This exploration has two different but connected tasks.

Number	1	2	3	4	5	6	7	8	9	10
Square	1	4	9	16	25	36	49	64	81	100

I	II	III	IV	V	VI	VII	VIII		I	II	III	IV	V	VI	VII	VIII
1	2	3	4	5	6	7	8		209	210	211	212	213	214	215	216
9	10	11	12	13	14	15	16		217	218	219	220	221	222	223	224
17	18	19	20	21	22	23	24		225	226	227	228	229	230	231	232
25	26	27	28	29	30	31	32		233	234	235	236	237	238	239	240
33	34	35	36	37	38	39	40		241	242	243	244	245	246	247	248
41	42	43	44	45	46	47	48		249	250	251	252	253	254	255	256
49	50	51	52	53	54	55	56		257	258	259	260	261	262	263	264
57	58	59	60	61	62	63	64		265	266	267	268	269	270	271	272

Fig.1. Snapshots of the tables used in Task 1 (left) and Task 2 (right)

In Task 1, a table of natural numbers and their squares is given and the teachers are asked to observe patterns in the table. In Task 2, a table of natural numbers up to 400 are arranged in an 8-column table and some square numbers are highlighted (see Fig.1, right) & again the same set of teachers are asked to observe patterns in this table. The hour-long session discussed some of the patterns, after which the teachers were given an assignment comprising of the following three questions:

1. Look at this table (Fig.1 (Task 1)) and find out two patterns. Verify them and prove or disprove them.
2. Prove Pratibha's pattern
3. Look at this table (Fig.1 (Task 2)) and find out two patterns. Verify them and prove or disprove them.

For this study, we look at only Q1 and Q3. Q1 was based on Task 1 which used a familiar arrangement of numbers and their squares used regularly in textbooks, while Q3 was based on Task 2, which used an unfamiliar arrangement of numbers.

Theoretical Framework

Openness of the tasks: Yeo (2015) includes the following five elements: openness of answers, methods, complexities, goals and extensions for characterising open explorations. The tasks (Figure 1) are both open in answer and method. It is practically impossible to come up with an exhaustive list of all the patterns that individuals engaging in these explorations can think about. Patterns that emerge while doing these tasks vary in complexity making it open to complexities involved. Though the task has a very specific goal, namely "Finding Patterns", it does not specify what types of patterns and hence even in the parameter of goals, one can say that in this exploration there is an openness of goals. This arrangement of numbers that is used in Task 2 enables the facilitator to extend this task and find patterns when the numbers are arranged in different numbers of columns. So even in the parameter of extensions, this exploration fulfills Yeo's criteria of an open exploration.

Classification of the proofs: In their book, 'Proof in Mathematics Education' (Reid& Knipping, 2010), the authors proposed a framework for categorising proofs. They made four broad categories of proofs based on the use or non-use of different representations in them.
Empirical – specific examples are used but these examples do not represent a general class
Generic – specific examples are used as representations of a general class
Symbolic – words and symbols are used as representations
Formal – words and symbols are used but they do not represent anything
Using the above framework, we categorise different proofs given by teachers in the context of their familiarity with the arrangement of numbers in the task. In this study, we look at 41 secondary teachers' assignments from three different sessions. We choose two out of the three assignment questions to see the different kinds of proofs teachers think of and how these proofs depend on their familiarity with the arrangement of numbers.

Research Questions

The study aims to address the following research questions:

- What are the different types of proofs teachers give when they prove 'new' results?

- Does the choice of type of proof depend on the teachers' familiarity with the arrangement of numbers used in the tasks?

Method and Findings

We analysed some of the proofs given by the teachers participating in the online sessions using the framework proposed by Reid & Knipping (2010) and compared their proofs for Q1 (based on Task 1) with Q3 (based on Task 2).

	Symbolic proofs	Empirical proofs
Q1 (Task 1)	60.97%	39.02%
Q3 (Task 2)	34.15%	60.97%

Table 1. Distribution of symbolic & empirical proofs for Q1 & Q3

Conclusion

It is known that in different contexts students believe in the validity of the statement but are unable to express or analyse it (Balacheef, 1988). From our data, it seems that even in case of teachers, in contexts unfamiliar to them; they seem to believe in the validity of their patterns but are unable to express them symbolically. Hence the way a problem is represented impacts the type of proof teacher chooses to prove a 'new' result.

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Ocularcentric Science Textbooks: Examining Visual Language and Resources in NCERT Class 6 Textbook

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This study investigates the critical role of textbooks in promoting equitable education, focusing on the accessibility challenges posed by science textbooks for visually impaired students. Employing linguistic hermeneutics analysis, the research examines the prevalence of visual language and reliance on visual resources in 6th-grade science textbooks. The findings reveal a high degree of ocularcentrism in language and content presentation, potentially creating significant barriers for visually impaired learners. This ocularcentric nature of science textbooks may hinder these students' access to fundamental scientific concepts, highlighting a crucial area for improvement in educational resource design and adaptation to ensure equitable learning opportunities for all students, regardless of visual ability.

Keywords: Ocularcentrism, Science Education, Linguistic Hermeneutical Analysis, Visual Impairment

Introduction

Textbooks serve as foundational resources for teachers and students in the educational journey, representing various curricular areas and playing a pivotal role in knowledge construction. The National Focus Group Position Paper on "Curriculum, Syllabus and Textbooks" (2006) emphasises the critical role of textbooks in promoting equitable education, particularly for marginalised groups. Furthermore, it advocates for textbook flexibility to accommodate the diverse needs of students. However, the design and organisation of science textbooks often present accessibility challenges for students with visual impairment. To address this issue, these textbooks are typically converted into Braille, large print, or audio formats. Nevertheless, these adaptations, especially Braille versions, often fall short of providing a comprehensive learning experience. The conversion process, particularly for Braille books, tends to be a direct translation of the printed text, including references to diagrams and visual resources. Problematically, these visual elements are frequently omitted from the adapted versions. However, the language of the text carries the visual elements to explain the content presented in the book, which is responsible for the accessibility issues faced by students with visual impairment. This discrepancy in content adaptation highlights a significant gap in the educational resources available to visually impaired learners, potentially hindering their full engagement with scientific concepts and compromising the equity in education that textbooks are meant to promote. In this paper, the researcher studied linguistic ocularcentrism of science textbooks, which influences the way text is perceived and understood while reading.

Theoretical Framework

The theoretical framework for this study is grounded in ocularcentrism, which is a dominance of visual perception, and it is often believed, especially in science, that seeing is equivalent to knowing (Palan, 2021). Morris (2016) argues that society's focus on visual perception results from cultural conditioning rather than a biological necessity, and science has privileged visual perception as it aids objective knowledge.

Research Questions

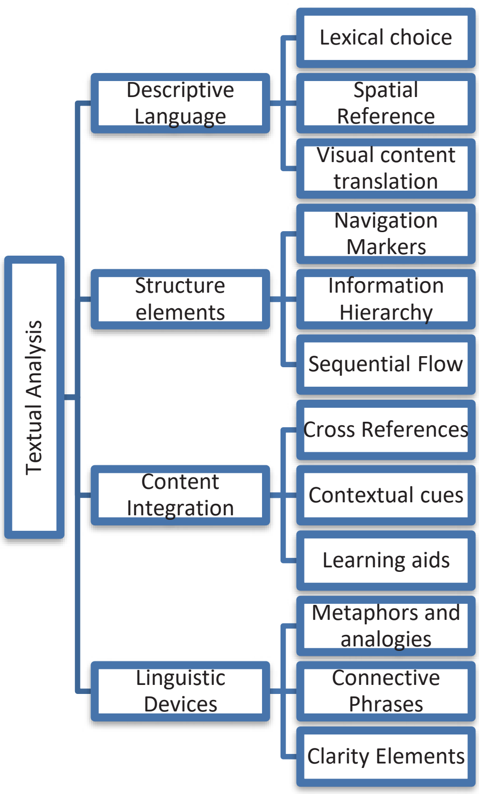
The study aims to address the following research questions:

- To what extent does the NCERT class 6 science textbook address the diverse sensory experiences of learners?
- To what extent does the textbook rely on visual resources to explain science concepts, specifically with respect to students with visual impairment?

Methodology

The study employs linguistic hermeneutics analysis as a research method. The textbook selected for the analysis was Class 6 Science (Hindi medium), published by NCERT in 2022 and rationalised in 2023-2024. Three chapters from the textbook were selected randomly for analysis. The selected chapters were 'Separation of Substances,' 'Getting to Know Plants,' and 'Body Movements.' A framework was developed to analyse the chosen chapters (Fig. 1). The researcher read the chapters for her initial immediate perception of the text and reread the individual chapter for the different elements of the linguistic analysis along with visual dependency of the textbooks based on the analytical framework developed in alignment with research questions.

Fig. 1 Framework for the science textbook analysis



Findings

The results indicate that the textbooks are highly visually dominated, whether in language or in visual resources used to explain concepts. Especially language is full of visual verbs, nouns, adjectives, and visual metaphors, for instance, verbs like *dekhna, prekshan karna, avlokan karna*, and visual metaphors, for instance*, dhoop khili ho, ve chatkile hain, sabhi pushp rang birange hain, sir bahar aate dekha, lehardar gati dikhayi deti hai.* Also, the text uses many visual resources, such as diagrams and pictures, to explain concepts and guide the procedure of activities. In many places, text refers to a diagram without any activity description. Although the text is organised in such a manner, it allows the reader to recall their previous experiences and use their kinesthetic sense by doing various activities. The ocularcentric nature of the textbooks potentially limits these opportunities for students with visual impairment.

Implications and Conclusion

In summary, while this visual-centric approach may engage sighted students by encouraging them to recall previous experiences and participate in hands-on activities, it poses significant challenges for visually impaired learners. The textbook's design, which often refers to diagrams without detailed descriptions, may inadvertently exclude students with visual impairments from fully accessing and comprehending the material. The textbooks are often designed primarily for sighted readers, neglecting the needs of visually impaired individuals. Kleege (2013) argues that visually impaired people share a visual culture with sighted people, where everything is designed by the sighted for the sighted. The solution is not to remove visuals but to design textbooks in a way that accommodates different sensory modalities. When translating books to Braille, textbook developers should consider alternative sensory experiences to help visually impaired readers understand the concepts. This study highlights the need for a more inclusive approach in textbook design, one that balances visual elements with alternative modes of explanation and engagement. Future revisions of science textbooks should consider incorporating multi-sensory approaches and detailed verbal descriptions to ensure equal access to educational content for all students, regardless of their visual abilities. Additionally, further research into considering students' experiences with visual impairment with textbooks and developing adaptive teaching materials and strategies that cater to diverse learning needs could contribute to creating a more inclusive educational environment.

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Complexity and Curriculum: The Importance of Connections in Mathematics and Science Education

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We present new insights into undergraduate mathematics and science education through the lens of network theory and brain studies, focusing on the importance of connections. The central questions addressed in this presentation are: (a)What is the network topology of a curriculum and how do we assess its merit? (b) How can network theory inform us about students' meaning-making process? and, (c) How does the brain react when creative connections are made? Our theory is exemplified through a first-year mathematics course. However, the outcomes of the study are generalisable to other science courses and programs as well.

Keywords: Mathematics Education, Networks, Meaning-making

Education as a Complex System

Systems theory suggests that the university is a veritable playground of ideas, and the job of teachers is to lay the groundwork to create connections for the students so they may freely roam and "play" in this space. Our job as teachers is not always to tell students what or how things "are;" there must be room in our education system for students to "create" new knowledge. In our study, we therefore model education as a complex system at various scales composed of different ideas and concepts through the lens of connections. Such a pedagogy, we argue, allows students to personalise learning and strive to be 'creative' which is making new meaning out of old ideas. Complexity theory speaks of a world of connections where the system is not a linear sum of individual parts "but the product of the parts and their interactions" (Davis & Simmit, 2003; Doll, 2015). To genuinely bring about such reform in the learning experience requires courses to be taught in a genuine interdisciplinary fashion with complete engagement of all the faculty and students (Park & Son, 2010). We contend that the collective implementation of such practices across all scales will inevitably lead to new ways of thinking and learning. Hiebert and Carpenter (2006, p.68) argue that seeing the "*Similarities and differences between alternate representations of the same information are relationships that can stimulate the construction of useful connections at all levels of expertise*." In our study, we examine the roles of intellectual (or conceptual) and emotional connections that are formed by students in their course of study. Learning entails a personal connection to the subject matter being learned is critical in addition to the conceptual interconnections within the subject itself. To further develop our understanding of how such connections might be formed and supported in a teaching and learning environment, we employ network theory and neuroimaging to illuminate the structures of student learning experiences. Such an approach enables us to compare and contrast content trajectories and emergent patterns across various intended curricula and their implications for student learning outcomes, as well as how these insights are relevant to teachers and curriculum designers.

A Network Model of Learning and Teaching

Neuroimaging. It is well known that students are most engaged in the classroom when the subject under discussion is of personal interest or something we recognise to have meaning to our lives (Chan et al, 2014); in other words, when the discussion is about ourselves. In this part of the presentation, we wish to validate this anecdote through brain studies experiments which implicate the different parts of the brain, such as Meical Prefrontal Cortex (MPFC), the right PFC (rPFC), the right Temporal Parietal Junction (rTPJ)), with self-awareness. Pilot Transcranial Magnetic Stimulation (TMS) and Electroencephalogram/Event-Related Potentials (EEG/ERP) studies conducted by our interdisciplinary team on a small sample of university students (N=7) provides clues on how self-awareness could impact the learning of mathematics (Keenan et al., 2022). Specifically, these aforementioned parts of the brain show increased activity and elicit better responses when questions in the study provide the opportunity to make personal connections (Fig. 1). These brain studies are supported by classroom surveys which show how students' knowledge networks and topics learned in class are connected to their own personal experiences. Therefore, in addition to focusing on 'what' we are teaching, we ought to equally consider 'who' is learning.

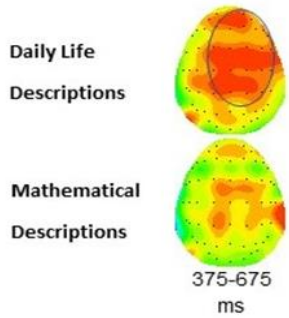

Fig.1. Brain activity when faced with an abstract problem versus one with a personal connection (daily life).

Curricular Networks: At the teaching level we have undertaken curricular network mapping of mathematics textbooks. There is an implicit assumption in our approach that texts reflect what is being taught (or at least the intended curriculum for a course) even though we realise that a gifted and experienced instructor can add greatly to these pre-written materials. In our model, topics in a text are nodes and a "deliberate connection" made between topics by the author (O'Meara and Vaidya, 2021) is an edge, allowing us to map an entire text as a network (see Fig.2).

Once represented as a graph, properties such as: its average path length, degree distribution, connectivity index etc. can be computed, all of which give us a glimpse of the structure of the course and its potential to allow free and easy flow of ideas which foster new emergent understanding and creativity. A comparison of the network structure of various textbooks and pedagogical practices help identify the kind of curricular plan that is likely to be most effective and creative. These networks inform us about the conceptual expectations of a topic and provide an *efficient map* for the flow of ideas.

In a second, related approach students participating in a survey made their own connections between the same topics identified in the text, periodically, across the entire semester. The outcomes of student surveys (N=116) were mapped to networks and analysed across three main quantitative dimensions: clustering coefficient, average path length, and the degree of the most highly connected topics in each student network (Hubs). Various other metrics, such as the number of connected components and modularity, were also considered in the analysis of each student network. Analysis of these metrics reveal that course outcomes (e.g., course grades) maintain a strong positive correlation with the depth of connections that students make.

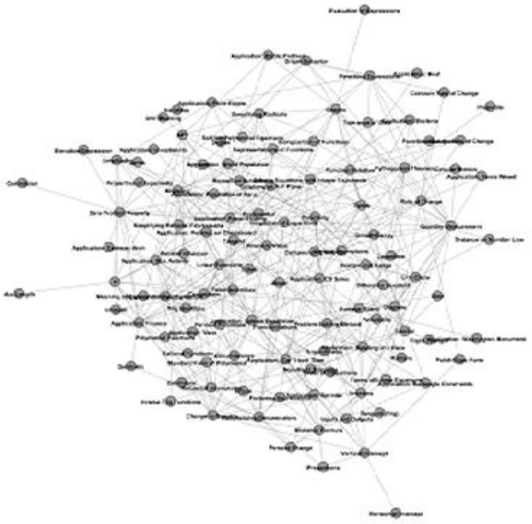

Fig. 1. An example of a network map of a math textbook on precalculus.

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Impact of Language Transition on Teaching and Learning of Mathematics in Kerala: A Preliminary Investigation

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In India, students in regional language mediums most often have to transition to English for higher education, with Kerala requiring this shift at the higher secondary level. This transition can pose challenges for both learners and teachers. To explore these issues, preliminary investigations were conducted in two higher-secondary mathematics classrooms in Kerala. Based on personal experiences and observations from the preliminary exploration, this paper proposes potential questions for a more systematic study.

Keywords: Higher-secondary Education, Kerala, Language, Mathematics Education

Introduction

The students in India, who study in a regional language medium often need to transition to English if they wish to pursue education beyond secondary school, though there are exceptions. In Kerala, where Malayalam is spoken predominantly, education is offered in both Malayalam and English up to the 10th grade, but higher secondary education (grades 11 and 12) is conducted in English. This transition from Malayalam to English can pose significant challenges for students in learning mathematics. This includes adapting to English, associating previously learned mathematical terms in Malayalam with their English counterparts, acquiring an understanding of sophisticated mathematical concepts and articulating their comprehension in English.

As a Malayalam medium student, for me transitioning to English was particularly challenging in mathematics. The challenges included the need to memorise the method for solving problems rather than understanding concepts, and it was only through my engagement with mathematics education that I realised these challenges are common and studied by math education researchers. To understand the persistence of these experiences among learners who are coming from the regional language medium, we carried out preliminary classroom observations in two grade 11 mathematics classrooms (one government and one government-aided school) in Kerala. This paper seeks to present some of the key observations from the classrooms.

Research on language in mathematics education began at least four decades ago and has since received worldwide attention. Geber et al. (2005) found significant performance differences between Afrikaans-speaking students based on the language of instruction in their tertiary education calculus classroom, attributing this to a lack of cognitive bilingualism. Durand-Guerrier et al. (2021) highlighted the challenges faced by second-language learners in mathematics across various countries in learning college mathematics. Even though there are studies around the world, there are only some studies in the Indian context. Subramanian and Viswanathan (2023) argued that the use of pure Tamil in textbooks alienates learners, while Khan (2008) explored the linguistic challenges in Hindi for early number acquisition. The Eklavya Foundation's Prashika program (Agnihotri et al., 1994) addressed difficulties with sanskritised Hindi in textbooks. While these papers focus on the issues of studying in the learners' home language, the article by Bose and Choudhury (2010) found that language negotiation in multilingual classrooms enhances understanding and participation. Sarabi and Gafoor (2017) conducted studies that focused on the language of mathematics in the Kerala context; however, they did not address the language used for communication.

Findings from our Exploratory Study

This field exploration aimed to gain a broader understanding of the challenges learners face when studying mathematics in English in grade 11 classrooms. Around 20 classroom observations were carried out in January 2024 in two schools (one government school and one government-aided school) in Kerala. The classroom observation notes were prepared and then the analysis provided the following findings: (1) Explanations of concepts and classroom interactions occurred primarily in Malayalam, with only technical terms being used in English. (2) The classrooms emphasised an algorithmic and problem-solving approach to teaching and learning. (3) Both teachers and students rarely used natural language in writing explanations. Instead, they primarily relied on symbols and used only a few terms such as 'prove,' 'show,' and 'shown.' (4) Academic interactions, such as asking questions and making comments, between teachers and students were minimal. Students rarely asked questions, and when the teacher asked questions, mostly in English, students often answered in few words. (5) Despite understanding the questions and providing answers orally when prompted, students were not writing down their responses. However, it should be noted that since it was revision time not all students were present, only the students considered weak were present in the classroom.

Conclusion

The extensive research worldwide highlights the critical role of language in teaching and learning mathematics. In India, even though the number of studies focusing on language in mathematics education is very minimal, there are works focusing on the challenges learners face while learning in their home languages. My own experience of transitioning from Malayalam to English medium in higher secondary school sparked my research interest in language in mathematics education. Preliminary observations in Kerala classrooms revealed the use of the Malayalam language for teaching, minimal academic interaction, and heavy reliance on English technical terms. This underscores the need to understand how students manage this transition, how teachers support it, and whether teacher education in Kerala adequately addresses the role of language in mathematics instruction. Since this is an exploratory study, we hope to conduct a systematic study to gain a deeper understanding of some of the language issues involved in teaching and learning mathematics.

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STEAM Learning at the Foundational Stage: Insights From the Water Table Experiments in Kindergarten

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Research in neurosciences has highlighted that 0-6 is the age for rapid and extensive brain development. Despite such evidences younger children are not studied as often as older children. NEP, 2020 suggests integrating national and international best practices and latest research on Early Childhood Care and Education (ECCE) in NCPFECCE. The review of the literature suggests that educators and policy makers across the globe have positive results about integrated STEAM components in ECCE. The researcher intended to develop a STEAM based leaning instructions and investigate its effectiveness in an ECCE learning environment. In the current paper the researcher designed the learning experiences based on WATER theme. The researcher studied the water play and activities and concluded that incorporating STEAM components cater to the holistic development of the children. The activities were mapped with the Curricular Goals and Competencies mentioned in the NCF-FS and the learning outcomes were assessed through observational schedules, event sampling, anecdotal records and rubrics.

Keywords: ECCE, STEAM, Curricular Goals, Competencies

Introduction

'Learning begins at birth' as mentioned in the opening remark of the concluding document of World Conference on Education, 1990. Even the societies which do not have the formal set up like schools, have their indigenous methods to pass on the culture and traditions to future generations. India has a tradition of valuing the early years of a child's life, and a rich heritage of cultural practices for stimulating development and inculcating "*sanskaras*" or basic values and social skills in children. In the past this was delivered primarily within joint families, through traditional child caring practices which were commonly shared and passed on from one generation to another. Informal learning of young children in a natural environment through songs, dance, play, and talk is a regular component of the childrearing responsibilities of adults in India. However, there have been changes in the family as well as social context in the last few decades. The changes in the social and economic structure of India have intensified the need for universal early childhood education.

National Education Policy, 2020 has put an end to frequently raised questions about worthiness of Early Childhood Education in the country and the low priority given so far to Early Childhood Care and Education (ECCE) and under valuing of the need and significance of ECCE is no longer justified. The policy stresses on the Universal provisioning of quality early childhood development, care, and education as soon as possible, and no later than 2030, to ensure that all students entering Grade 1 are school ready.

Rationale

The recent research studies suggest that the importance of early childhood education is though established the quality aspect remains a major issue. Even the ECCE curriculum framework starts on a note that "most of the ECCE programmes on offer currently do not have developmentally appropriate programmes for the young child." National Education Policy, 2020 stresses on investing early childhood education research especially utilising new pedagogical approaches. In recent years, educators and policy makers have shown increasing interest in STEAM education in early years in countries like USA, Australia, Korea, Malaysia etc. the close examination of basic tenets of STEAM and existing guidelines provided in the National Curriculum Framework for Foundational Stage (NCF-FS) have same underlying principles. Thus, researcher intended to develop a STEAM based program based on theme "Water" mapped with the Curricular goals and competencies mentioned in NCF-FS and study its effectiveness.

Research has shown that providing meaningful hands-on STEAM experiences for early childhood and elementary age children positively impacts their perceptions and disposition towards STEAM (DeJarnette, 2012). There are many benefits for young children from early exposure to STEAM. As the earliest espouser of the technological development and eager investigators, preschool children have a natural eagerness to explore STEM disciplines (STEM Smart Brief). Contrary to what is believed, preschool children wonder, reason and generate ideas about how the physical, social and biological world around them work (National Research Council). They permanently explore, experiment and engage in all sorts of tools, solve problems, compare things (Sharpan, 2012) and interrogate facts and rules. Indeed, notwithstanding their ability, pre-schoolers are ready, eager and be able to deal STEM activities. Early Childhood Education Programmes necessarily focus on introducing Environmental Concepts to children between age 3 to 6 years. The environmental concepts can be related to:

1. The Natural Environment
2. The Physical Environment
3. The Social Environment

These environmental concepts may be taken as projects or a theme for a planned period of time as suggested by Kaul, 2009. The concepts like colour, number, shape time, temperature etc., can all be introduced to children through these themes.

For the concepts related to the physical environment, Water, Air, Sky, Earth and Weather are the most appropriate and popular concepts dealt in Preschool. For the present study, researcher has selected Water as the theme.

Research Questions

- How to develop STEAM education-based programme for ECCE?
- How STEAM education-based programme can be implemented in an early childhood learning environment?

Methods and Findings

As per the objectives of the research study the qualitative research design was used. The methodology used was Embedded Case Study. The sampling was purposive. The data was collected through Classroom Observation Protocol, Video recordings, students' work samples, interview with Early childhood educators.

Conclusion

The findings suggest that young children are STEAM ready and they tend to learn concepts when provided with enough opportunities to explore, experiment, innovate and create. The classroom is happier when they are provided with unstructured as well as structured play time. The competencies like estimation, observation, gross motor skills, early numeracy concepts, vocabulary, communication gets enhanced when young learners are introduced to STEAM learning experiences. Playing with water has a calming effect on the young children. It increases their attention span. Pouring water from one vessel to another helps in development of co-ordination of multiple muscles. Water plays and activities related to it help in the introducing the concept of measurement, estimation, solubility, sink and float etc.

Image 1-2. Young learners experimenting on the water table and exploring the concepts of solubility, volume and shapes.

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Effect of STEAM-Based Learning on Mathematical Creativity of Middle School Students

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The present study aimed to examine the effect of STEAM-based learning to foster mathematical creativity of middle school students. Experimental method followed with two groups pretest-posttest control group design was used to conduct the study. Based on the mathematical intelligence scores, the group of 40 eighth-grade students were formulated into experimental and control groups equally through random selection and random assignment. Self-developed mathematical creativity test and mathematical intelligence test were used to collect the data. The result shows that STEAM-based learning was found significantly effective to foster mathematical creativity. Educational implications and directions for further studies are also outlined.

Keywords: Mathematical Creativity, STEAM Approach, Mathematics Education, Middle School Students

Introduction

Creative thinking is one of the most significant skills of the twenty-first century which generates new ideas with values and seeks the solutions of the problems to ensure sustainable development (NEP 2020, Ervynck, 1991; Singh, 1987). Due to the scientific and technological advancement, in this digital era, everything is being digitised into binary systems i.e., zero and one, therefore, modern technology is transforming the entire education system globally. Ergo, mathematical thinking has taken a prime position in upcoming fields like big data science, machine learning and artificial intelligence (NEP 2020). Therefore, environment should be provided to the students to learn mathematics with joy rather than fear that encourages students to think out-of-the box (NEP 2020) and try to relate Mathematics with the real-life settings and reflect mathematisation of mind (NCF 2005).Therefore, in order to develop the creative potential of students, various policy documents stressed to use integrated and innovative pedagogical practices like STEAM-based learning, experiential learning and game-based learning (NEP 2020; NCFSE, 2023).

Theoretical Framework

Mathematical creativity, one of the greatest assets of a nation (Singh, 1987) plays a pivotal role in advanced mathematical thinking (Ervynck, 1991) and ensures the growth of the field of mathematics as a whole (Sriraman, 2004). It is considered the major component of education in 21^{st}-century skills. It consists of the following dimensions *Fluency, Flexibility, Originality* & *Elaboration*. The multiple solution problems from real-life settings provide opportunities to formulate new problems by using generalisation, analogy, and the idea of converse that helps students to develop their creative thinking in mathematics (Leikin, 2009).

According to Yakman (2008), STEAM- the fusion of five fields of studies i.e., Science, Technology, Engineering, Arts and Mathematics, is widely accepted as an educational approach to foster 21st century skills like critical thinking, creative thinking and problem-solving skills (NEP, 2020; Vincent-Lancrin et al. 2019).

It provides opportunities for the students to think outside the box, and express innovative and creative ideas. (See Fig 1.)

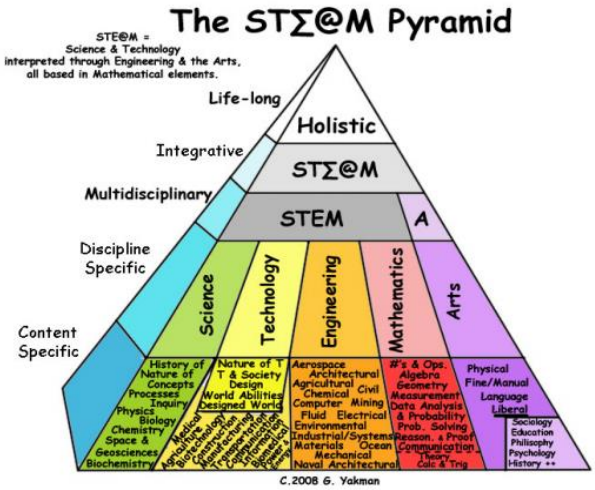

Fig 1. The STEAM Pyramid

Research Question

The study aims to address the following research question:

- What is the effect of STEAM-based learning on mathematical creativity of middle school students?

Methodology

Experimental method followed with two groups pretest-posttest control group design was used to conduct the study. The groups of 40 eighth grade students were formulated into two equal groups based on mathematical intelligence test scores (M & SD) through random selection and random assignment and considered as experiment and control groups. A self-developed mathematical creativity test (pretest & posttest) was administered on both the groups. After providing the STEAM activities-based intervention like- like paper-cutting activity for garland, key-activity, pattern of matchstick, clock activity, division of figure, mathematical properties through STEAM activities, milk container & weighing, nine dot figure, understanding pattern and thinking diagonally, real-world problems (sprinkler), four-four to five-five task, tangram activities and scientific thinking through nature, based intervention was given to experiment group for 40 days (one class of 40 minutes per day) for the experiment group. After converting the raw scores into T-scores, ANCOVA and t-test were used to analyse the data.

Conclusion

Based on the findings, it is concluded that the effect of STEAM-based learning was found significantly effective to foster the fluency, flexibility and originality dimensions of mathematical creativity of middle school students. Further, it is also pointed out based on the interaction with the students that multiple solution tasks provide ample opportunities to the students for their equal participation and engagement in the mathematics classroom discourse. The findings of the study will be helpful to school teachers, researchers and educational professionals for understanding the processes of mathematical creativity.

Despite having the methodological strength of the study, the findings of the study may face the problems for its generalisation because of the short period of experiment, involvement of rural students only without considering the psycho-social factors, and no use of triangulation techniques like interview with school mathematics teachers and their parents. Ergo, longitudinal studies and cross-lagged panel studies are needed to confirm the findings of the study by which a support system could be developed to foster students' creative potential in mathematics.

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A Case Study of Cyanotype Techniques as a Pedagogical Tool for Teaching Chemistry

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The cyanotype process, a non-silver photographic technique using light-sensitive iron salts to produce deep blue images, has been known for centuries. However, its use has declined in art and education over time. This work revisits the cyanotype method as a valuable educational tool for teaching chemistry to secondary and higher secondary students. The technique involves the preparation of a coordination compound, potassium tris-(oxalato)ferrate (III), which forms the chemical basis of the experiment. By creating cyanotype photographic paper directly in the classroom, students can observe firsthand how a photographic image emerges from the chemical treatment on ordinary drawing paper. This approach offers a creative and engaging way to teach various chemistry concepts such as coordination chemistry, photochemistry and observation of new compounds. Additionally, case studies on the cyanotype process demonstrate how varying light sources and exposure times affect the final image, providing a comprehensive understanding of photochemical principles. The reintroduction of this technique in the classroom not only enhances chemistry education but also integrates artistic creativity, making science learning more interactive and appealing for students.

Keywords: Cyanotype, Photochemistry, Education, Iron Complexes

Introduction

Cyanotype, an iron-based photographic printing process, is part of the Siderotype group of techniques. First introduced in 1842 by Sir John Herschel to the Royal Society, this method derives its name from the Greek word *cyan*, meaning "dark blue." Cyanotype relies on light-sensitive materials that react to strong ultraviolet rays. Historically, it was widely used by engineers and architects for reproducing technical drawings, a practice that gave rise to the term “blueprinting”.

Research Questions

The study aims to address the following research questions:

- How do hands-on activities, such as creating blueprint paper, enhance students’ understanding of photochemistry concepts?
- What role do safety and procedural awareness play in shaping students’ approach to experimental science?

Methodology

This study employs a *developmental experimental approach* to design, implement, and refine a cyanotype-based learning activity aimed at enhancing students' understanding of photochemistry and coordination chemistry. As the activity is still in the experimental phase and has not yet been integrated with student groups, these studies will serve as a foundation for future implementations.

Chemical Reaction and Steps

- The cyanotype process involves mixing potassium ferricyanide and ferric ammonium citrate to prepare a photosensitive solution.
- When exposed to UV light, Fe (III) reduces to Fe (II), which reacts with hexacyanoferrate (III) to form Prussian blue.
- Students will create blueprint paper, expose it to light using objects as stencils, and develop their images by washing with hydrogen peroxide and water.

Participants and Engagement

- Higher secondary students will participate in pairs, fostering collaboration and discussion.
- Students will be actively involved in each step, from preparing the solutions to analysing the final blueprints.
- Teachers will guide students through reflective discussions, connecting observations to theoretical principles.

Questions Explored

- How does UV light influence photochemical reactions?
- What role do Fe (III) ions play in forming coordination compounds?
- How do exposure time and materials affect the final blueprint?

Cyanotype Process Overview

The schematic in Fig.1 showcases the cyanotype process, where a prepared canvas with arranged leaves and flowers is exposed to UV light for approximately 15 minutes, resulting in the final cyanotype print on the right. The process captures the intricate details of the objects on a blue background, highlighting the contrast between the exposed and unexposed areas.

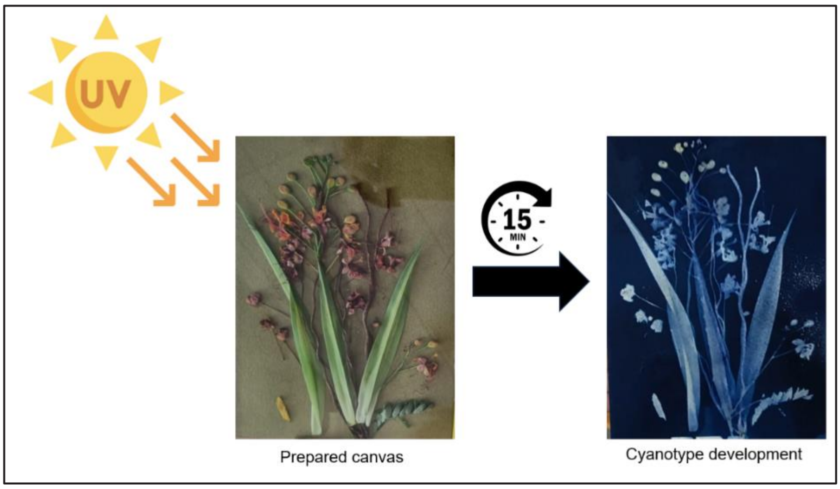

Fig.1. Cyanotype development using UV light exposure

Conclusion

The cyanotype process bridges science and creativity, providing students with an opportunity to engage in hands-on learning while exploring photochemistry and coordination chemistry concepts. Integrating this experimental approach into classroom will help in developing interdisciplinary approach and students will able to connect scientific principles with real world applications.

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Igniting STEM Learning Through Rocket Design and Experimentation

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The learning of interdisciplinary sciences strengthens by project-based learning and activity-oriented models. While approaching multiple subjects and putting the right amount of combination of those subjects can be observed and analysed better with the help of such methods. Considering the subject of 'Model Rocketry' as the base, in this work I have tried to observe the learning patterns and the correlation between the application of the knowledge and skills in multiple degrees. The research is intuitive and based on multiple methods of execution. The subject covers multiple other subjects as source of knowledge and skills and is a fit in the context of STEM education as it positively covers all the fundamental aspects of STEM and design thinking in the right amount. The study involves various workshops conducted with different grade students ranging from class five to working teachers with interactions containing model making, understanding 3D designs and working on simulations. I believe this study can be valuable in the application of the new education policy and understanding the idea of activity-based learning.

Keywords: STEM Education, Project-based Learning, Model Rocketry, Interdisciplinary Sciences

Introduction

STEM learning has garnered a liking in fostering involvement of interdisciplinary sciences and design thinking in the curricula as a part of the New Education Policy 2020.

One day, I was conducting such session on the topic of making of a model rocket, after listening to a half an hour introductory session on why the fins of the rocket should be in a certain way, a student rose and asked 'Why waste such time on the theory when we can figure out the process by experimenting on the fins by ourselves?'. She was right and I understood that everyone has a different approach and one should have a chance to explore the process by themselves and observe what learning curve they take. It triggered me to make short duration modules that involve various degrees of self-understanding and induced information.

This study is my interpretation of the involvement of various factors in the application of STEM based learning in the mainstream education system. I come across various age group of students who involve themselves in projects of three categories: 1) One day projects of their own theme; 2) One day projects of my theme; 3) Five-day projects of my theme.

The general domain of my interaction falls under the umbrella subjects of Model Rocketry, Aeromodelling and Prototype designing. In these subjects, we conduct the workshops by three ways: 1) Working model design 2) 3D display model making 3) Understanding through computer generated simulations.

Theoretical Framework

The theoretical framework for this study is grounded in the conceptual change theory, which suggests that misconceptions are persistent and require active, reflective engagement for students to revise their mental models (Posner, Strike, Hewson, & Gertzog, 1982). According to this theory, misconceptions are deeply embedded in students' cognitive structures, and they must undergo significant cognitive conflict before they can be replaced with scientifically accurate conceptions. Furthermore, this study draws on the constructivist perspective of learning, which asserts that learners build knowledge through experiences and interactions with their environment (Vygotsky, 1978). This approach emphasises the importance of social interaction and the active role of students in constructing their own understanding of scientific concepts.

Methodology

Average workshop duration: One and a half hour to two hours.

Motive of workshop: Explanation of the theory, introduction to the model, figuring out motivation to implement the discussed ideas and variations in the design, understanding the possibility of failures, discussion on the results. This may be easier to express taking one module as an example.

Components of model rocket design:

1. Body Tube – Effects of size and material on the stability and flight dynamics.
2. Stabilizers – Effects of size, material and shape on the aerodynamics and trajectory.
3. Nose cone and counter weight – Effects of drag and the centre of gravity works on the model.

Procedure followed by the students:

1. Design phase – Designing of rockets considering various components.
2. Construction phase – Making of rockets using the provided material and guidelines.
3. Testing phase – Testing of the rockets by launching and calculating distance and other parameters.

Findings

1. Performance metrics – Describing how the performance of each rocket is evaluated i.e. apogee distance, stability, turbulence.
2. Learning outcomes – What students learn about rocketry through the workshop.

Through this integrated approach, it encourages the student to experiment, iterate and approach a topic from their design outcome and grasp the interdisciplinary nature of the subject. The same approach can be used in a broader aspect with other learning modules and subjects as well. I opt out of putting graphs and charts here as I believe the data of my findings would resonate better during interaction.

Conclusion

This study is a tool to understand the application of integrating multiple subjects with one another and an experimentation platform to iterate various permutations and combinations of multiple subjects. The most interesting aspect that I have come across is that the module is flexible with all age groups. The same workshop method can be applied for students ranging from primary sections to adults. Integration of hands-on experimentation with theoretical knowledge engages students of all ages, stimulates their creative design thinking and problem solving.

It exemplifies how STEM approach is effective in the mode of short duration project-based learning workshops. The insight gained from this study has a potential to induce creative discussions and achieve betterment in the approach. Furthermore, it can be eligible for adoption in similar strategies to develop a more engrossing, holistic and efficient learning environment.

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A Preliminary Study on Intervention: Evolving Technologically Enhanced Learning units to Build the Skill of Strategising in Logical and Geometric Problem Solving Among the Learners of Grades 7 to 10

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The data considered for this study is from a question pool of a skill-based assessment that evaluates students' conceptual understanding called Ei ASSET in the strands of logical and geometrical problem solving among Grades 7 to 10 reveals that the highest accuracy in these strands is around 45% on average. This study focuses on the pedagogy involved in evolving digital interactive learning units to address these gaps by introducing different strategies such as case wise analysis, elimination grids and others to structure logical and geometric problems verbally and visually. This study highlights the accuracy achieved in learning unit on strategies in logical problem solving and in geometry in contrast to the benchmarking test and interventions that are planned to evolve these pedagogical approaches.

Keywords: Critical Thinking, Problem Solving, Strategies for Problem Solving, Geometrical Reasoning, Technology-enhanced Learning Units

Introduction

OECD Learning Compass 2030 emphasises on the skills of critical thinking, problem solving and learning to learn as the demands for 21st century competencies which are also focus areas in teaching and learning mathematics (OECD 2020, NCF 2005). Many experiences of teachers found that problem solving can be difficult to teach and even more difficult for students to learn (Larry, 2004). Experiential learning and integration of technology to improve multiple aspects of education is recommended in school curriculum and pedagogy (NEP 2020). Our present work focuses on identifying challenges faced by the learners in solving problems in two areas- firstly, geometry problems involving multiple properties and critical thinking; secondly, logical problems and evolving technology enhanced interactive learning units to build these skills and remediate the gaps.

Theoretical Framework

The theoretical framework for this study is grounded in Polya's method of problem solving of intervention containing a four-step process: understanding the problem, devising a plan, carrying out the plan, and reflection. The area of focus is to build learning units in geometry and logical problem solving that involve strategising solutions using scaffolding structures like Polya's method, case-wise analysis, mathematical reasoning through flow diagrams, grid representations and other visual strategies and interactives instead of seeking direct answers to the problems. The larger goal is to encourage learners to use this exposure to build their own strategies and use them for effective mathematical reasoning, communication and problem solving.

Research Questions

The study aims to address the following research questions:

- Does creating learning units on strategies for problem solving improve students' performance in solving critical logical thinking problems?
- Does creating learning units on strategies for problem solving improve students' performance in solving problems involving application of multiple geometrical properties?
- What question types are effective in building the skill of strategising and what question types help in identifying specific learning gaps and mistakes in such critical thinking problems on logic and geometry?

Methodology

This study uses questions from a few rounds of Ei ASSET in the areas geometry and logical problem solving of the Grades 7 to 10, whose accuracy is around 50% for analysis.

Gaps in these learning objectives and challenges in these concepts and question types were identified. The primary challenge encountered by the learners these areas is to identify the sequence in which the question can be solved and to justify each part of this sequence mathematically or logically (depending on the area of focus). So, learning units were built to strengthen this aspect of problem solving. The indicator items in these units were made cognitively close to the Ei- ASSET items. Two question types were extensively used: i) Questions that involve drag and drop interactives for mathematical reasoning, elimination and sequencing the strategy. ii) Multiple True or False (MTF) questions and questions with multiple blanks and drop downs. Data was analysed on the basis of comparison between similar items in the assessment and the learning units, questions that require conceptual understanding of one or more concepts in geometry versus those involve purely logical reasoning and the question types used in the learning units.

Findings

The user response data currently shows that the accuracy of indicator items in logical problem-solving learning units is ~70% in comparison to the accuracy of ~46% in similar Ei ASSET questions. The Multiple True or False questions also give an insight into learner inferences and misconceptions while answering such questions through Free Response (FR), further allowing us to understand what interventions are needed. The learning units on Geometrical problem solving are still at lower performing levels below 40% accuracy levels.

Conclusion

Performance of the learners, so far, suggests that the skill of strategising is empowering them in improving their logical problem-solving abilities. It also suggests that for critical thinking problems in geometry which involve recall and knowledge of some middle school geometric properties, building strategy alone is insufficient, but the learner competencies in translating these strategies into framing and solving equations and be able to justify them are also equally necessary. Pedagogical interventions such as identifying incorrect sequences of reasoning as well as identifying and justifying multiple correct approaches for solving a problem are under development for enhancement.

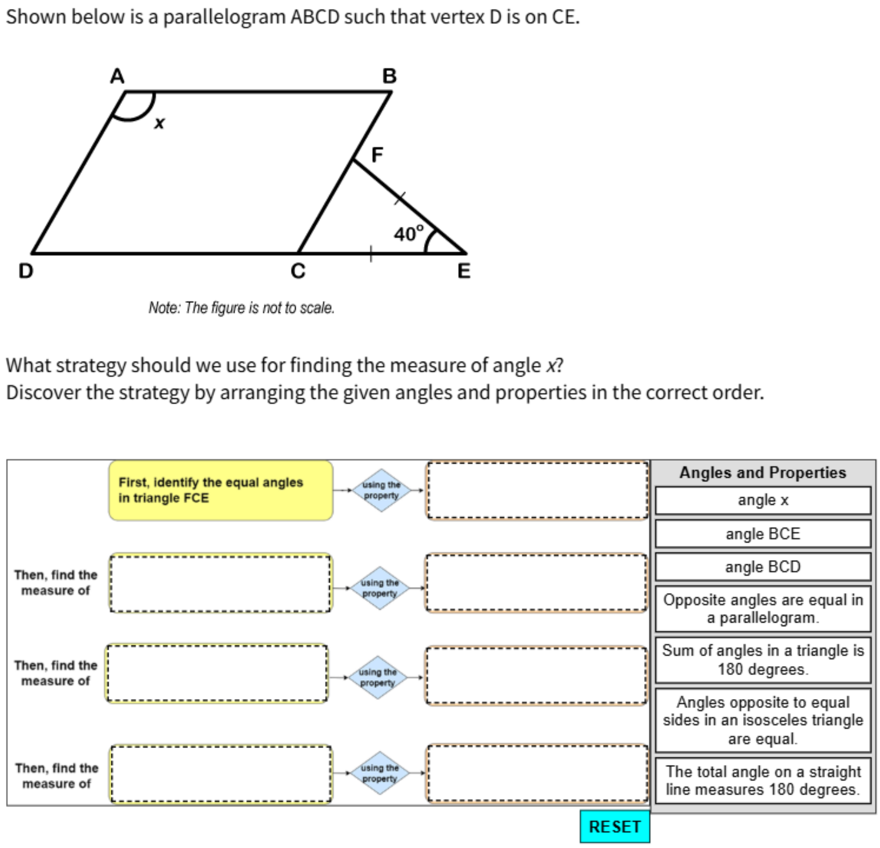

Fig. 1. Interactive based question to help learners discover strategy for solving a geometrical problem

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Emotional Engagement in STEM Education

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This study investigates the impact of emotional engagement on students' learning outcomes in STEM (Science, Technology, Engineering, and Mathematics) education, focusing on how emotions influence understanding and retention. Employing a mixed-methods approach, the research collects data from students in grades 7–10 through surveys, classroom observations, and standardised tests, supplemented by teacher interviews. Emotional states such as enjoyment, anxiety, and frustration are examined alongside academic performance to uncover patterns and correlations. Preliminary expectations suggest that emotional engagement significantly affects students' ability to grasp complex STEM concepts, with positive emotions enhancing performance and negative emotions posing challenges unless supported by teachers. The study underscores the importance of integrating emotional engagement strategies into STEM education to foster holistic development, aligning with the vision outlined in NEP 2020.

Keywords: Emotional Engagement, STEM Education, Holistic Development, NEP 2020

Introduction

STEM education (Science, Technology, Engineering, and Math) has become crucial in equipping students with skills like critical thinking and problem-solving, essential for succeeding in the modern world. However, traditional STEM education often focuses predominantly on academic achievement, neglecting the emotional dimensions of learning. Recognising this gap, India's National Education exploring how emotions like curiosity, frustration, or excitement influence students' ability to understand and retain STEM concepts. This study is grounded in the dual-process theory, which categorises brain function into two systems: *System 1:* Quick, intuitive, and emotion-driven. *System 2:* Slower, deliberate, and logical. In STEM education, emotions from System 1 can significantly impact how students approach and solve problems. For example, feelings of curiosity can drive exploration, while frustration might act as a barrier to learning. This framework aligns with NEP 2020's vision of creating emotionally engaging and supportive learning environments that cater to the holistic development of students.

Theoretical Framework, Research and Research Questions, Original Aspects

The study bridges the gap between emotional engagement and STEM education by examining the interplay of emotional and cognitive processes in real-world classroom settings. By focusing on middle and high school students (grades 7–10), the research highlights emotional influences on conceptual understanding, retention, and problem-solving abilities in STEM. The originality of this research lies in:

- Applying the dual-process theory to STEM learning.
- Exploring emotional engagement in diverse educational contexts (urban and rural).
- Investigating teacher strategies to address emotional dynamics in classrooms.

Research Questions

The study seeks to answer the following questions:

- How does emotional engagement affect students' understanding and retention of STEM concepts?
- What are the primary emotional factors influencing STEM learning (e.g., curiosity, frustration, anxiety)?
- How do teacher interventions impact the emotional states of students and their academic performance in STEM?

Methodology

The study employs a *longitudinal mixed-methods design,* with data collected over one academic year.
Participants: Students from grades 7–10 across urban and rural schools.
Data Collection Tools:

- Surveys: To capture students' emotional responses (enjoyment, anxiety, frustration, interest).
- Classroom Observations: To record real-time emotional and behavioral responses.
- Standardised Tests: Administered at three intervals (beginning, middle, and end of the year) to evaluate academic progress.
- Teacher Interviews: To gather insights on emotional engagement strategies and classroom practices.

Analysis

Quantitative data from surveys and tests will be analysed statistically, while qualitative data from observations and interviews will be thematically analysed to identify patterns and relationships.

Findings

The anticipated findings include:

- *Positive Emotional Engagement:* High levels of curiosity and enjoyment correlate with better understanding and retention of STEM concepts.
- *Negative Emotional Impact:* Frustration and anxiety hinder learning but can be mitigated with teacher support.
- *Balance of Emotions:* A combination of positive and negative emotions promotes resilience and adaptability in learning.
- *Role of Teachers:* Classrooms with emotionally supportive teachers lead to higher academic success and emotional regulation among students.

Conclusion

The study emphasises the integral role of emotional engagement in STEM education. Emotional states are shown to influence not only cognitive outcomes but also the overall learning experience. The findings are expected to align with NEP 2020's goals of holistic education by providing actionable insights for integrating emotional engagement into STEM curricula.

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Exploring Mathematisation Ability of Mathematics Pre-Service Teachers

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This study presents an analysis of the response of pre-service mathematics teachers to some real-life situations in terms of mathematisation. The aim of the study was to explore their responses in terms of i) what is the variety in responses to a particular situation and ii) what is the level of mathematisation in their responses – horizontal and vertical.

Keywords: Mathematisation, Pre-service Teachers, Real-life Situations

Introduction

It is more useful to know how to mathematise than to know a lot of mathematics (Wheeler, 1982). Infact, 'mathematisation' is a popular and integral notion during the teaching of mathematics, and the goals related to mathematics education at school level in India have been also highlighted by few documents (NCERT, 2006; NCERT 2023). After publication of the position paper on teaching of mathematics (NCERT, 2006), this term is widely used by teacher educators and pre-service teachers in India while teaching and studying a paper 'Pedagogy of Mathematics' in teacher training courses. Mathematisation means to making mathematics out of something (Drijvers, 2020) and has been classified into horizontal and vertical mathematization (Freudenthal, 1991; Van den Heuvel-Panhuizen & Drijvers, 2020).

Keeping this ability in mind, the authors, with a quest to understand the mathematisation ability of the pre-service teachers, developed a self-developed questionnaire consisting of 5 items and administered to the students of B.Sc. B.Ed. programme. They were asked to express these situations mathematically. Pertaining to these 5 items based on real life situations, we were interested to know how students think and react to these situations. Students who study the course 'Pedagogy of Mathematics' during their B.Sc. B.Ed. programme in a central institution of India were selected for this study (Semester VI and Semester VIII). Each student was provided with a task sheet with 5 items, with the only instruction written as: '*Describe or represent these items mathematically as far as possible'*. They were also provided an hour to express these tasks mathematically on a separate sheet of paper. The responses of the students were evaluated based on diversity and variety of their ideas; use of words, diagrams and symbols-expressions for a particular item. Results revealed that most of the students used 'words' to express the situations mathematically. There were also instances of non-mathematical responses to a particular item.

For example:

'During Covid, there is a shortage of necessary products and their price is also rising. If you don't purchase these, you might lose necessary products, but if you get out of home to get

necessary products, you might catch covid. What would you prefer? Represent the situation mathematically.'

Though this situation involved aspects of game theory, graphs which depict the relationship between price and demand, some students wrote 'online shopping' as a response in this case, without representing the situation mathematically. Another aspect of the study also brings out results related to their level of their mathematization for a particular item (in terms of horizontal and vertical). This is an ongoing study and has been done on a small scale, and there can be also various lens of analysis related to it.

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A Survey of Barriers in STEM Learning in Higher Education Among Rural Youth in India

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Higher education plays a significant role in preparing rural youth for STEM career goals. However, the rural youth face barriers and challenges in this pursuit resulting in a low proportion of students accessing and excelling in higher education STEM programs. In this context, the present study tries to understand these barriers that students find hindering their higher education. The study was conducted using a survey at undergraduate level and their responses were analysed using thematic content analysis to seek insights into their challenges. The study has implications for providing support at academic and institutional levels.

Keywords: STEM Career, Higher Education, Rural Youth, Barriers, Undergraduate Biology Education

Introduction

Higher education plays a pivotal role in empowering rural youth, offering them the knowledge and skills necessary to improve their socio-economic status and contribute to the development of future generations (NEP, 2020). STEM (Science, Technology, Engineering, and Mathematics) education is crucial for fostering innovation and economic development of the country. However, in India, rural youth face unique challenges that hinder their pursuit of higher education in STEM fields (Halfacree, 1993). Factors such as inadequate access to quality education, limited resources, socio-economic constraints, and cultural perceptions contribute to a significant disparity between urban and rural students in learning abilities (Kanar & Christy, 2015; Matthew et. al., 2014). The proportion of students excelling in higher education, from rural areas remains relatively low (Henley & Roberts, 2016). This study aims to identify and analyse the specific barriers faced by rural youth in India in accessing and succeeding in higher education STEM programs. Understanding these obstacles is essential for developing targeted interventions to bridge the gap and empower rural communities with the skills necessary for future STEM workforce.

Theoretical Framework and Objectives

We project the study under the STEM workforce as a conceptual framework (Roehrig, 2021) that helps to identify problems and gaps between skill development and career aspirations. The STEM workforce framework (Roehrig, 2021) envisages building an ecosystem at individual, educational, academia, industry, and government levels. With this background and concerns, the objective of this study is to determine the barriers in higher education among rural youth. The study might significantly recognise and acknowledge rural communities with the critical skills and knowledge necessary to thrive in the evolving future STEM workforce, ensuring they can actively participate in and contribute to emerging research and development projects. Our specific research questions are about what kinds of barriers the students face; despite the barriers what is their motivation in higher education; what kind of support system they expect and require; how prepared they are for skill development and STEM career goals.

Research Questions

The study seeks to explore the following research questions:

- How do challenges in understanding academic language, including Latin/Greek terminologies and instructors' language, impact the interest and learning outcomes of rural youth in STEM education?
- What role does transportation difficulty and associated mental health challenges play in hindering STEM learning among rural college students, and how can interventions like yoga, meditation, or counselling address these issues?
- To what extent do career support, financial aid, and English language skills influence the motivation and aspirations of rural youth to pursue STEM careers in higher education?

Methodology

Considering the objectives of the study, a survey method seemed appropriate and was adopted. A set of questions was prepared with possible responses that emerged during discussion with students. The questionnaire had 16 categories and was reviewed by peers before administering to the students. An online survey was conducted using which the students provided their responses over a week's time. Given the rural context, online responses were sought due to the accessibility of their smart phones. Wherever applicable, the students had the choice to provide their own responses. The sample comprised of n=230 students (male=34 (14%); females=196 (86%), age range=17-21 years) all belonging to STEM education at undergraduate level. The responses were qualitatively analysed for thematic content analysis which emerged into categories.

Findings

In this study, we are discussing only 5 categories – discipline-specific barriers, personal barriers, motivation, support system, skill development.

Discipline-specific barriers

Difficulties in understanding the content knowledge have been one of the major barriers in STEM discipline-specific learning among the rural youth. Students' responses indicated, 84% students had to struggle with developing interest in the subject, due to difficulties associated with academic language (46%). Within the language barrier, students had difficulty in Latin/Greek words, and meanings; and faced challenge in understanding instructor's language.

Personal Barriers

One of the major concerns reported by the students was about transportation as a hindrance as they had to travel very long distance from far rural areas to reach college every day. About 40% of students reported that due to the difficulties in learning they were facing mental health issues, and even emphasised that yoga, meditation, counselling, etc. could be beneficial.

Motivation, Support System, Skill Development

Cumulatively more than 90% of students have mentioned career support, financial support and language support would help them to continue in higher education and showed aspirations in STEM career goals. When asked about the requirement of additional skills, most of the students opted for the English language to be a barrier in understanding and needed this skill the most.

Discussion and Conclusion

The National Education Policy (2020) "Envisions a complete overhaul and re-energising of the higher education system to overcome challenges and thereby deliver high-quality higher education, with equity and inclusion". In this context, it is essential that we are aware of the barriers faced by the rural youths while pursuing higher education. Through this study, we tried to at least highlight these barriers and hurdles, to create opportunities for students in their pursuit. Further, focus-group or individual interviews could provide in-depth insights into their challenges and requirements. We envisage providing opportunities to the rural youth in the form of government support through inclusive learning opportunities, providing active learning through hands-on workshops, content orientation exposure camps, organising wellness camps, field visits, using multimedia technology to enhance classroom learning, using multilingual teaching learning materials, learning and skill-building across education and professional training environments, contextualised teaching, experiential learning, providing internships, preparing for employability skills, vocational education to create STEM workforce, etc.

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How Large is That Number? Understanding How People from a Social Science Institute Estimate Large Numbers

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This study investigates how individuals from a social science institute estimate large numbers using the lakh, crore system on a number line task. Participants were asked to estimate the location of large numbers from real-world contexts on a number line with labelled endpoints. Results revealed a significant tendency to underestimate large values, aligning with cognitive models like logarithmic and segmented scaling. This mirrors findings from Western contexts (million, billion), suggesting universal cognitive biases in estimating large magnitudes. Understanding these biases provides insights into numerical cognition and highlights the need for educational strategies to improve numerical literacy.

Keywords: Indian Number Systems, Numerical Estimation, Numerical Cognition, Cognitive Biases

Introduction

Mistakes in estimating large numbers (LN) (here, numbers beyond 10^{11}) are frequently reported in the media. It is a common struggle people face when dealing with numerical magnitudes in real-world contexts. It is not just a cognitive challenge; it impacts decision-making in sectors such as economics, policy-making, and education. Research in numerical cognition has explored how people represent and estimate LN, showing that estimation strategies are often biased. This study aims to investigate how individuals from a social science background estimate LN using the lakh/crore system, as opposed to the more commonly studied million/billion system. Specifically, our research question is: How do people from a social science institute estimate LN of orders 10^{11} to 10^{13} on a number line task?

Related Literature

Siegler and Opfer (2003) introduced the number line estimation task, revealing that people often use logarithmic or segmented models instead of a purely linear approach, particularly for handling numbers across different scales. Landy et al. (2013) extended this work by exploring how participants estimate LN in the context of millions/billions. Their study showed a consistent pattern of underestimation, indicating that individuals mentally compress large scales, often treating segments like thousands, millions, and billions as distinct cognitive blocks. This segmentation reflects a deeper cognitive strategy where different mental rules are applied across number ranges, highlighting a shift between linear and non-linear thinking. Batt et al. 's study (2008) supports these findings, demonstrating that estimation accuracy declines as numbers increase, with a persistent bias towards underestimation. Dehaene et al.'s (2008) work emphasised the brain's tendency to encode quantities logarithmically, suggesting that people default to a more segmented or compressed view of LN even when attempting to think linearly.

Despite these insights, the role of different numerical systems, like the lakh/crore used in India versus the million/billion system, remains relatively underexplored. The shift in magnitude representation (jumps of "100" in lakh/crore vs "1000" in million/billion) between these systems could influence estimation strategies.

Methods

There were 29 participants from various schools and centres of a social science institute, representing diverse educational backgrounds. The participants' ages ranged from 23 to 41 years.

Task Design: A number-line estimation task was adapted from Siegler and Opfer (2003) and further modified by Landy, Silbert, and Goldin (2013). Participants completed six estimation tasks based on real-world statistics, such as national budgets and contemporary events involving LN. For each task, participants estimated the position of a number on a number line with labelled endpoints of 0 to 50 lakh crores.

Procedure: Participants were informed that their data would be used for research and completed the tasks anonymously. The task was explained before starting, and participants' estimations were compared to the correct answers. Deviations were calculated as percentages to assess overestimation or underestimation.

Analysis Process: The responses were analysed to identify patterns of estimation bias, quantifying both the frequency and magnitude of over/ underestimations for each question.

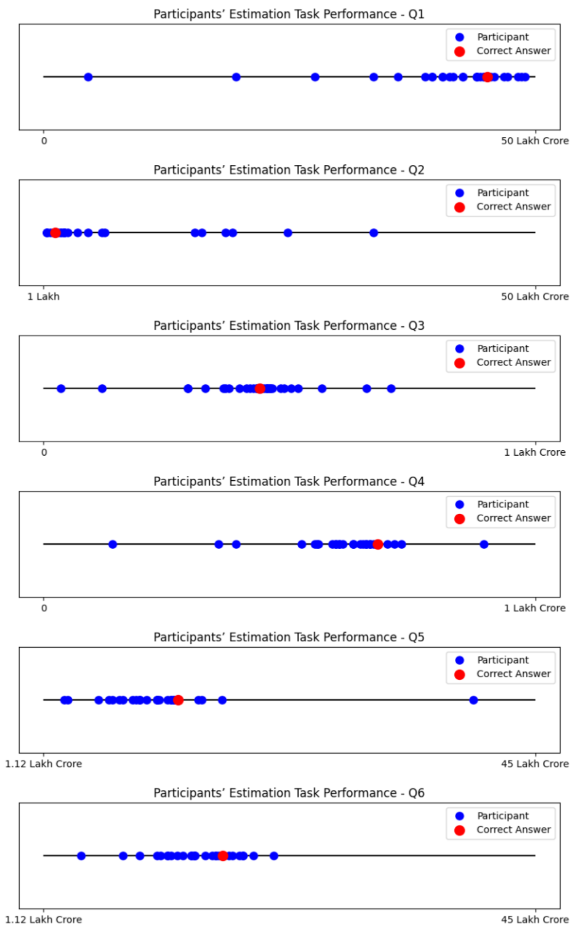

Fig. 1. Plots showing participants' performance on six tasks

Findings

This study aimed to investigate how participants estimate LN using the Indian number system. Our analysis focused on participants' tendencies to overestimate or underestimate LN.

Overestimation and Underestimation Tendencies: Participants' estimations of LN showed distinct patterns of underestimation (see Fig 1). A Wilcoxon signed-rank test revealed that the tendency to underestimate was statistically significant (W = 0.0, p = 0.03125), unlike the test for overestimation (W = 0.0, p = 0.125). This suggests that participants consistently placed LN at a lower position on the scale. It mirrors Landy et al.'s (2013) results, which demonstrated that people often struggle with accurately placing LN on a linear scale, leading to systematic underestimation. Despite the difference in numerical systems, the similarity in outcomes suggests that the cognitive mechanisms underlying numerical estimation may be universal, though their expression can vary with context.

Cognitive Models of Number Estimation: The significant underestimation observed supports the hypothesis that participants may be using a segmented or logarithmic cognitive model when estimating LN. As in Landy et al.'s (2013) study, participants in our study likely relied on non-linear scaling, particularly when dealing with numbers that span several orders of magnitude. Despite comparatively smaller incremental jumps in the Indian number system, this scaling issue persists and poses a cognitive challenge.

Discussion and Conclusions

These results indicate that the tendency to underestimate LN is prevalent in both Western (million/billion) and Indian (lakh/crore) contexts. Despite the cultural and educational differences in numerical representation, the underlying cognitive biases in number estimation might also be consistent across systems. However, as the sample size of this study was small; therefore, the results have limited generalisability. Overall, our findings contribute to the broader understanding of numerical cognition. These insights could inform educational strategies aimed at improving numerical literacy. Demonstration of number line through a string could be a possible strategy to teach LN.

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Strand 3

New Media and STEM

Role of ICT in teaching-learning

AI and STEM education

Interdisciplinary STEM education and Design thinking

Visuo-spatial thinking

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Impact of Science Communication on STEM Aspirations of Tribal Girls in Bastar

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This study explores the impact of science communication programmes on the STEM career aspirations of tribal girls in Bastar, India. Focusing on educational TV shows and community outreach initiatives, the research examines how culturally relevant science communication influences girls' interest in STEM fields. Findings reveal that these programmes significantly boost curiosity, confidence, and aspirations among participants, despite challenges such as socio-economic constraints and cultural biases. The study emphasises the importance of community engagement, teacher training, and gender sensitisation to overcome these barriers and empower tribal girls, contributing to both individual and community development through STEM education.

Keywords: Tribal Girls, Bastar, STEM

Introduction

This study investigates the influence of science communication programmes on the career aspirations of tribal girls in Bastar, India, particularly in the fields of Science, Technology, Engineering, and Mathematics (STEM). Bastar, known for its diverse tribal communities, faces a multitude of socio-economic challenges that severely limit educational opportunities for girls. The region is characterised by inadequate infrastructure, cultural biases that discourage girls from pursuing STEM fields, and economic constraints that hinder access to quality education and resources. Existing literature highlights how these barriers often result in low educational attainment and limited career prospects for tribal girls. The pressing need for effective interventions that can address these challenges and promote inclusive development forms the basis for this research.

Theoretical Framework

The study adopts a theoretical framework grounded in social equity in education. This framework emphasises the importance of equitable access to educational resources and opportunities, particularly for marginalised groups such as tribal girls. Social equity in education asserts that educational success should not be determined by one’s background or socio-economic status but rather by the quality of resources and support available to them. By focusing on science communication as a vital tool for empowerment, this study aims to highlight how effective educational interventions can create pathways for tribal girls to enter and succeed in STEM careers.

Research and Research Questions

The research centers on two primary science communication initiatives: educational television shows and community outreach programmes. The educational TV shows, inspired by successful models like the Satellite Instructional Television Experiment (SITE), are designed to disseminate scientific knowledge in ways that are accessible and culturally relevant. These shows utilise storytelling and local languages, making complex scientific concepts understandable and engaging for rural and tribal audiences.

Community outreach initiatives complement these programmes by providing hands-on experiences through interactive sessions, workshops, and mentoring programmes in local schools and community centers. The study aims to answer the following research questions:

- How do educational TV shows and outreach initiatives influence STEM career aspirations among tribal girls?
- What are the original aspects of these initiatives in the Bastar context?

Original Aspects

The original aspects of the initiatives lie in their culturally relevant approach to science communication. Educational TV shows leverage local narratives and familiar storytelling techniques, making scientific concepts relatable to tribal audiences. This method not only disseminates knowledge but also fosters a sense of belonging and ownership among viewers. By featuring local role models—women who have successfully pursued STEM careers—the programmes aim to inspire young girls to envision themselves in similar roles.

Community outreach initiatives are particularly significant because they provide direct engagement opportunities. Through workshops, girls can participate in hands-on experiments, receive mentorship from female scientists, and engage in discussions about STEM careers. This experiential learning approach is vital for building confidence and interest in STEM subjects, enabling girls to see the practical applications of what they learn.

Methods and Findings

This study employs qualitative case studies and interviews to assess the impact of science communication programmes on tribal girls. Participants include girls engaged with educational TV shows and outreach initiatives, along with their families and educators. Findings indicate a significant positive impact, with many girls reporting increased interest in STEM subjects and newfound confidence in pursuing related careers. These initiatives not only foster curiosity about science and technology but also encourage girls to challenge traditional gender roles within their communities.

However, persistent challenges remain. Barriers such as inadequate infrastructure, cultural stereotypes, and socio-economic limitations hinder progress. Many girls face pressure to conform to societal expectations that prioritise traditional roles over education, and the lack of ongoing support and resources can diminish the long-term effectiveness of these programmes.

To address these challenges, the research emphasises the importance of community engagement in sustaining interest in STEM education. Actively involving families and community leaders can help shift cultural attitudes toward girls' education. Teacher training and gender sensitisation programmes can enhance the effectiveness of these initiatives by equipping educators with the tools to better support girls in STEM fields.

Conclusion

The study highlights the vital role of science communication programmes in inspiring tribal girls in Bastar to pursue STEM careers. By providing access to knowledge and fostering a supportive environment, these initiatives challenge traditional barriers limiting girls' educational aspirations. Addressing issues like inadequate infrastructure, cultural perceptions, and gender biases is crucial for sustainable impact.

Empowering girls through STEM education not only enhances their individual ambitions but also significantly contributes to the socio-economic development of their communities. The skills and confidence gained allow them to envision futures that were previously unattainable, breaking the cycle of inequality. Engaging families and communities help shift cultural attitudes toward girls' education in STEM, creating a more encouraging atmosphere for their growth. As these girls enter fields traditionally dominated by men, they pave the way for future generations, demonstrating that gender should not dictate potential.

Ultimately, empowering tribal girls through STEM education enriches their lives and enhances community well-being. The findings underscore the need for ongoing investment in science communication programmes, which can create lasting change and foster a more equitable society, ensuring that girls in Bastar and similar regions have the opportunities they deserve to thrive.

A Biology Unit to Support NEP and NGSS Aligned Learning

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National and global education reforms emphasise 21st-century curricular skills, practices and capacities needed for science learners, including Computational Thinking (CT), and Scientific Inquiry (SI) (NEP, 2020; NCFSE, 2023; NGSS Lead States, 2013). We present a CTSI-integrated biology unit on the Excretory System for 11th grade that includes agent-based computational models, inquiry-based activities, and media prompts. We investigated its alignment with NEP and NCFSE. Our findings show the unit supports the aforementioned skills, practices and capacities with an example and could serve as an exemplary resource for educators to implement NEP and NCFSE.

Keywords: Computational Thinking, Scientific Inquiry, Co-design

Introduction

Computational Thinking and Scientific Inquiry (CTSI) practices are the practices that scientists engage in to construct knowledge using computational tools and methods. The aim of integrating CTSI into school curricula is to go beyond knowing and understanding scientific concepts and to learn the "knowing how" to make sense of phenomena using contemporary science practices. This approach is in alignment with NEP's recommendation to develop 21st-century skills and NCFSE, 2023's aim to develop 'capacities' of Inquiry, Communication, and Problem Solving and Logical reasoning (1.3.2 a, b and c of NCFSE, 2023). CBSE's handbook for 21st-century skills (2020) describes the skills "*that are required by an individual for his/ her holistic development so that he/she can contribute to the progress and development of his society/ nation and world.*" We use these documents to analyse a co-designed biology curricular unit that is integrated with CTSI practices. We present the structure of the unit, how it engages students in CTSI practices and the analysis of its alignment with 21st-century skills (CBSE, 2020) and capacities (NCFSE, 2023).

Theoretical Framework

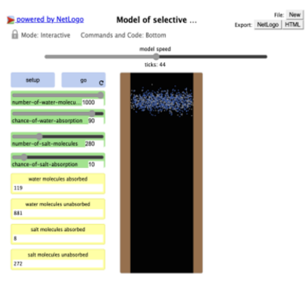
Our theoretical framework of CTSI practices is based on Science and Engineering Practices of Next Generation Science Standards (NGSS Lead States, 2013) and Weintrop et al., 2016's taxonomy of Computational Thinking practices for science education (Fig. 1).

Fig. 1. Framework for CTSI Integration (NGSS Lead states, 2013; Weintrop et al., 2016).

We co-designed a CTSI-integrated high school biology unit on the Excretory System with a biology teacher. We investigated the following research question to study the alignment of the unit with NEP and NCFSE: *How does a co-designed CTSI integrated curricular unit align with 21st-century skills and capacities recommended by NEP and NCFSE?*

Methods and Findings

We analysed the alignments of the curricular activities of the CTSI integrated biology unit with the practices, capacities and skills listed in Fig. 1. In Fig. 2, we provide an example of an activity and the mapping of its alignment.



Question - If you want to investigate the functioning of the ascending loop of Henle, how will you set the model? Mention the parameter values.

CTSI Practice	Developing and using models and simulations
Capacity	Inquiry
21st Century Skills	Technology and information literacy

Fig. 2. An agent-based computational model of “Model of selective absorption” (left) and its associated inquiry prompt and CTSI practices, capacities, and skills (right).

We will present the complete structure of the curricular unit with examples of alignment with the NEP and NCFSE recommended capacities and skills.

Conclusion

This work provides an exemplary unit for supporting students to develop 21st-century skills and capacities that are recommended by NEP and NCFSE.

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Does AI Change Our Beliefs?

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Artificial Intelligence (AI) has entered our lives in unprecedented ways. Incorporation of AI in various online platforms and search engines has added to its popularity. Youth forms one of the largest consumer bases of this technology, and much of the technological advancement is geared towards its needs and demands. In turn this compulsive technological intrusion is gradually changing our lives and probably stealthily our mindset. However, interestingly much of its potential is just beginning to get explored with a lot of disruptive speculation about the social transformation it will bring about. Education being one of the most crucial parts of the society, plays a role in reflecting as well as transforming it. Thus, it is important to understand what kind of changes this technology is bringing about in the educational settings? How are the stakeholders using it? What purposes is it fulfilling? What are their experiences? What potential does it hold for them? And most importantly how this technology is shaping our epistemological beliefs. This research is an endeavour to gain insight into these questions at the higher education level.

Keywords: Artificial Intelligence, Epistemological Beliefs, Science Education

Introduction

ChatGPT, Meta, Gemini, Siri are some of the new entries in our daily vocabulary. Their ingress into our mobile phones has further ensured their constant presence and involvement in our daily lives. Whether we open Google or WhatsApp, AI is hovering all over. It has become almost impossible to remain untouched with its omnipresence in the digital world. There are many attributes which make it a compelling technology and enhances its utilitarian value. Most of the basic versions are free of cost and easily accessible, creating a compulsive temptation for the users to utilise it. Its feature of amalgamating content from various digital resources and creating a comprehensible piece makes it better than any search engine. Moreover, its convenient interface combined with the ability to provide responses in human-like languages adds to its attractiveness and extensive usage. Its exponentially increasing consumer base is therefore not a matter of surprise.

Education, like any other sector, couldn't have remained untouched. Exploration of its potential in and out of the classroom is at a nascent stage and researchers have just begun to investigate its utility and effectiveness in the teaching learning process (Ramkorun, 2024; Polverini & Gregorcic, 2024; Piccione et al., 2024; Wulff, 2024). We do have a couple examples from Kerala and Bangalore where humanoids like IRIS (KTCT School) and EAGLE (Indus Bangalore) have been made a part of the classroom. However, their effect on the teaching -learning process is yet to be seen in its entirety. AI is speculated to bring in disruptive social changes and government policies too are supporting the transformation (NEP, 2020); however, it is yet to enter the formal education system. Nevertheless, students are increasingly getting drawn to it. With its user-friendly nature, free and easy access, it is gaining popularity amongst learners. Unlike any other human being or search engine, it responds to all their prompts. It also solves problems and in this competitive multitasking world, the feature of instant solutions is very appealing. This research is an endeavour to gain insight into these questions at the university level.

Theoretical Framework

The theoretical framework for this study is grounded in the lay epistemic theory (Kruglanski, 1989) for analysis on beliefs. This theory focuses on an individual's epistemological beliefs with respect to two aspects, perceptions of epistemic authority and need for certainty. Epistemic authority talks about the extent of authoritativeness of a source of knowledge and need for certainty talks about the extent to which the uncertainty of knowledge will or will not be considered by the individual (Fulmer, 2014).

Research Questions

The study aims to address the following research questions:

- What kind of changes this technology is bringing about in the educational settings?
- How are the stakeholders using it?
- What are their experiences?
- What potential does it hold for them?
- And most importantly, is the effect contained to pragmatic levels or has it deepened to the way we think and act?

Methodology

The study is located in the qualitative paradigm where we wish to understand science students' experiences with AI and take a peep into their epistemological beliefs. The beliefs render themselves for an in-depth interaction where we try to understand their subjective realities. This is a part of a larger ongoing project. For this particular study we are collecting data using semi structured interviews from around 30 science students from higher education institutions. The data is categorised into various themes. Findings shall be presented thematically.

Conclusion

The research in the area of AI and Education, specifically in Science Education, are usually focused on various teaching - learning interventions and their effectiveness (Yeadon & Hardy, 2024, Zollman et al., 2024, Polverini & Gregorcic, 2024). However, considering this technology is speculated to be disruptive bringing about social transformation, there is a need to look deeper and understand its potential to alter the way we think and act. This research is intended to add value by unravelling those deeper epistemological beliefs.

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Case Study: B. Sc. Blended – A Unique Interdisciplinary Programme with the Soul of NEP 2020

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The B.Sc. Blended programme implemented in 2016 in India, in collaboration with University of Melbourne, rooted in NEP 2020 principles, offers an interdisciplinary approach to STEM education by blending Interdisciplinarity, critical thinking and design thinking. This study explores the program's impact on students' academic growth, interdisciplinary skills, and career readiness, as compared to traditional B. Sc. programmes. Using qualitative methods, findings highlight the programme's success in integrating experiential learning through projects, internships, and outreach, fostering critical thinking and problem-solving skills. Graduates demonstrate high adaptability and global competitiveness, securing positions at prestigious institutions. This programme serves as a benchmark for future interdisciplinary educational models, addressing contemporary educational needs.

Keywords: NEP2020, Interdisciplinary Education, Critical Thinking

Introduction

The B.Sc. Blended programme embodies the principles of NEP 2020, promoting an interdisciplinary approach that blurs the boundaries between traditional disciplines. The theoretical underpinning of the B. Sc Blended programme in collaboration with University of Melbourne (2016) is rooted in interdisciplinary education, critical thinking and design thinking principles (Razzouk & Shute, 2012) which are highlighted in the NEP 2020. The programme emphasises experiential learning through projects, internships, and research, offering a holistic assessment of student capabilities, much needed in today's diverse job market. Unlike traditional Bachelor of Science programmes, the B. Sc. Blended framework builds on contemporary theories of multidisciplinary learning, where boundaries between disciplines are fluid, promoting creative solutions to real-world problems (Ledford, 2015).

Research and Research Questions

This study aims to explore the impact of the B.Sc. Blended programme on students' academic growth, interdisciplinary skills, and career preparedness. Key research questions include:

- How does the B.Sc. Blended programme enhance students' understanding of interdisciplinary science?
- What is the programme's unique contributions to student skill development compared to traditional B.Sc. programmes?
- How does the integration of NEP 2020 principles affect student outcomes?
- What is the impact of experiential learning in STEM (Kolb, 1984; Bybee, 2010) and design thinking methodologies on students' overall academic and personal growth?

Original Aspects

The B.Sc. Blended programme's originality lies in its holistic approach to education, which integrates the core components of NEP 2020, ahead of its time (2016). Its originality lies in the collaboration with international institutions, such as the University of Melbourne, offering students a global perspective while maintaining a curriculum that addresses national educational goals. The curriculum is designed collaboratively with international and national institutions, ensuring global exposure and adherence to high academic standards. It emphasises experiential learning through research projects, internships, and industry collaborations, allowing students to apply theoretical knowledge in practical settings. The inclusion of co-curricular and outreach activities further enriches students' educational experiences, fostering leadership, creativity, and social responsibility.

Methodology

This study employs a case study methodology, drawing on qualitative data from curriculum analysis, student performance metrics, and feedback from faculty and students. The findings indicate that the programme successfully integrates interdisciplinary pedagogy (Repko, Szostak & Buchberger, 2017) and design thinking into its curriculum. Students gain hands-on experience through interdisciplinary research-based projects (Borrego & Newswander, 2010) intern-ships, and participation in outreach initiatives like the ISRO Space Tutor programme. Assessment methods are varied and holistic, including presentations, video creations, and project work, which enhance students' problem-solving abilities and adaptability.

Findings

Key outcomes observed include a high level of critical thinking and interdisciplinary application among students, with graduates effectively demonstrating the ability to address complex scientific and societal issues. Students have actively engaged in community outreach, spreading awareness of environmental issues, and participating in global research projects, which have greatly enhanced their learning experiences. The programme's emphasis on research and hands-on learning prepares students for competitive exams and higher education opportunities both nationally and internationally. Alumni have secured positions in prestigious institutions like the University of Oxford, University of Melbourne, and various Erasmus Mundus programmes, showcasing the programme's success in equipping students for global challenges.

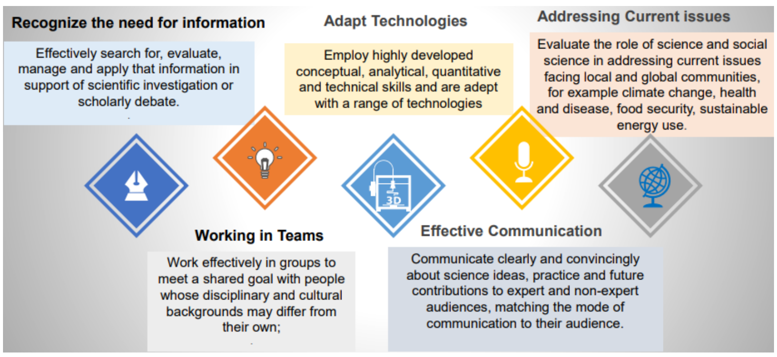

Fig. 1. Extraordinary graduate outcome of B Sc Blended Students.

Conclusion

The B.Sc. Blended programme at SPPU exemplifies the vision of NEP 2020, offering a unique and effective model of interdisciplinary STEM education. The integration of design thinking into STEM education is a crucial aspect of the B.Sc. Blended programme, promoting creativity, innovation, and practical problem-solving skills (Razzouk & Shute, 2012). The programme's innovative curriculum, holistic assessment methods, and emphasis on experiential learning foster a deeper understanding of science's role in addressing societal issues. The findings suggest that the B.Sc. Blended programme not only answers the research questions by demonstrating its impact on skill development and academic growth but also sets a benchmark for future interdisciplinary educational models in a very short time after its conception. The outcomes of the programme reflect that the pedagogy, syllabus, methods, approaches and all other tools that are incorporated in the programme have been effective and can be projected as a role model for the forthcoming programmes.

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Unlocking the Complexity of Biological Systems Through Analogy-Based Approach

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Teaching complex biological systems is challenging, and traditional methods often fall short. This study investigates the potential of an analogy-based approach to enhance comprehension of biological concepts, focusing on "heredity" using the "family tree" analogy, which is based on structure, function, and behavior. A lesson plan incorporating this analogy was implemented with secondary school students (n=50), and paired t-tests revealed a significant improvement in comprehension. The findings highlight the effectiveness of analogies in biology education, offering valuable insights for educators and curriculum developers. This research underscores the potential of analogy-based approach to simplify complex biological concepts, promoting deeper student understanding.

Keywords: Structure Behavior Function, Analogy, Complex, Biology Education, Complex System

Introduction

Teaching complex biological systems poses significant challenges due to their intricate interactions and dynamic nature, often exceeding the capabilities of traditional methods (Dauer & Dauer, 2016; Housh et al., 2022). To address this, educators are exploring innovative approaches such as analogy-based approach, which links unfamiliar concepts to familiar scenarios to enhance understanding (Ameyaw & Kyere, 2018). Analogies act as cognitive bridges, aiding comprehension and retention by drawing parallels between different domains. Interactive activities also improve understanding of abstract biological concepts like diffusion and cellular transport (Karakoyun & Yapici, 2018). Combining analogical teaching with interactive activities creates a more engaging learning experience. Our research focuses on an analogy-based lesson plan with interactive activities for teaching heredity concept, using the "family tree" analogy based on Structure-Behavior-Function (SBF) theory (Gentner, 1983). The study aims to evaluate the impact of this approach on students' comprehension of complex biological systems.

Theoretical Background

Analogies help individuals understand new concepts by comparing them to familiar ones. Analogies expand existing knowledge and aid cognitive development by connecting known and unknown ideas (Gentner, 1983). SBF theory is instrumental in designing effective analogies by focusing on similarities in function and behavior, even when structural differences exist. This theory breaks down complex systems into structures (elements), behaviors (interactions), and functions (roles) (Hmelo-Silver et al., 2007). Applied to teaching, the SBF theory has been used to develop augmented reality tools that enhance comprehension of complex systems, such as the human circulatory system (Gregorčič & Torkar, 2022). The study applies the SBF framework to create an analogy-based lesson plan on heredity, using the "family tree" analogy.

Design of Analogy Based Lesson plan

The intervention involves a lesson plan using the analogy "the story of a family tree" to teach heredity. This analogy helps students relate complex biological concepts like genetics, inheritance, and natural selection to familiar real-life scenarios. The lesson plan includes interactive activities such as creating personal family trees and identifying inherited traits, which serve as tangible representations of genetic principles. Students engage in mapping activities based on the SBF, linking elements of heredity to the family tree analogy. For example, inherited physical traits represent structural aspects, family skills reflect functional traits, and genetic recombination is likened to diverse family characteristics. Assessment methods include quizzes and individual activities to evaluate students' comprehension and application of these concepts.

Method

This study employs a mixed-methods approach to assess the impact of an analogy-based lesson plan on secondary school students' understanding of heredity. The research question is: *"Do analogy-based lesson plans enhance students' comprehension of complex biological systems at the levels of structure, function, and mechanism?"* Fifty students participated, with data collected through pre- and post-tests, mapping activities, and interviews. The SBF theory guided the evaluation, and paired t-tests compared pre- and post-test scores. Qualitative data from classroom activities were thematically analysed to enrich the findings.

Findings

Paired t-tests revealed a significant improvement in comprehension, with post-test scores ($M = 21.3$) significantly higher than pre-test scores ($M = 13.2$), $p < 0.001$. This indicates that analogy-based lesson plans with activities substantially enhanced students' understanding of heredity, demonstrating its effectiveness as a teaching tool for complex biological concepts. The qualitative data reveal that analogy-based lesson enhances students' learning experiences. Students reported increased engagement and interest due to relatable "family tree" analogy, which made complex concepts like heredity more accessible. One student noted, "*The analogy brought concepts to life and made me more curious about genetics*." Interviews highlighted that analogies aligning with students' cultural contexts enhance their understanding, as one student said, "*The analogy spoke my language and made concepts feel personal."* The findings underscore the value of using analogies in science education to connect with students' experiences, enhancing their comprehension.

Discussion and Conclusion

The study demonstrated a significant improvement in students' comprehension of heredity concepts through analogy-based intervention. These findings align with previous research that underscores effectiveness of analogy-based pedagogy in promoting understanding and retention of complex concepts. The significant improvement in learning from the pre-test to post-test underscores the pedagogical value of analogies (Cardinali et al., 2022). While the findings support the integration of analogies in biology education, limitations such as a small sample size and focus on a single analogy suggest the need for further research with diverse analogies and larger cohorts. The study underscores the importance of relevant analogies in designing effective biology lessons.

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Using Design Thinking to Develop an Educational Game

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This work presents a brief overview of the design and development of an educational game on financial literacy (FL). The game aims to offer middle school students the opportunity to engage in fundamental FL actions of spending, saving, and account-keeping, while also introducing the concept of risk. The work touches upon how we used design thinking (DT) as a framework to develop the educational game and shares some preliminary insights from student trials.

Keywords: Educational Games, Design Thinking, Game-based Learning, Financial Literacy

Introduction

Amongst the many ways to enhance teaching learning, educational games have started to gain recognition amongst researchers across the globe. Subject-specific educational games, including those in mathematics, have demonstrated potential in enhancing the learning of concepts and skills for both students and teachers (Husain, 2011). The current study describes the design and development of an educational game based on financial literacy (FL), using a design thinking (DT) framework.

Theoretical Framework

Scholars have argued that educational games can not only be intrinsically motivating, but also can be based on deep learning principles. Typically associated with game-based learning, educational games can play a crucial role in cultivating interpersonal skills, sharpening analytical and evaluative thinking, fostering imaginative thinking, improving problem-solving techniques, encourage risk taking, engage in social skills (McFarlane, et al., 2002). Building on the insights derived from game-based learning research, we embarked on the development of an educational game focused on FL for middle school students, utilising a design thinking framework. As a systematic problem-solving approach, design thinking (DT) offers numerous affordances in education, assisting both students and teachers in various ways (Goldman & Zielezinski, 2016). We used a DT framework (Plattner, dschool Stanford), as our approach to design and develop an educational game, which comprised of iterative phases of Empathising, Defining, Ideating, Prototyping and Testing.

Case Study of FunDHAN

This project began with curiosity about financial literacy (FL) stemming from personal experiences. The initial research phase involved two tracks: examining FL in school curricula and understanding the needs of students, parents, and teachers. We analysed FL content in Maharashtra's textbooks for classes 6-10 in mathematics and social studies and conducted surveys and interviews. Insights from this research helped define educational objectives and challenges related to FL. In the ideation phase, we brainstormed various concepts for teaching FL to children, which included an interactive installation, role-playing activities, table-top games etc. We also explored existing games around FL so as to gain a holistic perspective of the topic. After assessing these ideas based on constraints like cost, scalability, school logistics, etc., we developed FunDHAN, an educational card game. The next stage was prototyping which required us to make a sample of our chosen idea. In the game, players accumulate health points, desire points, and savings by completing missions using need cards, which involve a mix of health and desire scores at a cost, along with risk elements like dice rolls. We refined the game through prototyping and user feedback, testing it with students in informal settings to evaluate its effectiveness. This iterative process ensured that the game was both educational and engaging, ultimately aiming to improve FL among children.

Observations and Way Forward

Feedback from the initial deployment indicated that most students found the game easy to understand, and the cards funny, attractive and colourful. Majority believed that this game could help them to improve their idea of money. Students reported learning various skills from playing the game, including improved calculation abilities, the importance of saving money, and careful decision-making. They also reported having gained insights into managing money wisely, balancing desires and needs, and knowing when to take risks. While our initial trials have shown positive results, we aim to further optimise the visual design, game mechanics, and content to better align with educational goals and user needs. We also plan to include a teacher handout with the game that can offer prompts for discussions on the mathematics and social aspects involved in the game.

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Exploring Undergraduate Students' Interpretation of Misleading Graphs in Public Media: A Case Study

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Contemporary news media frequently utilises graphs to simplify the presentation of complex information. However, prevalence of misleading graphs on public platforms often makes readers susceptible to false information. This raises pertinent questions regarding the efficacy of our education system in adequately preparing students to interpret graphs. In this study we explored undergraduate students' interaction with misleading graphs and unpacked their mathematical reasoning as they do so. The study's findings suggest that students who focused on the data in a graph, rather than its shape, demonstrated better proficiency in graph comprehension and in identifying misleading elements.

Keywords: Graph Literacy, Media, Misinformation, Critical Mathematics

Introduction

Today, most of the news media uses different forms of visualisations to simplify the presentation of complex information. While graphs can significantly improve information processing, the prevalence of misleading graphs in news and public media exposes readers to false information and poses a significant threat to democracy (Cairo, 2014). Under such circumstances, the question remains to what extent are students prepared to interpret graphs and identify misleading graphs published on public platforms? This paper presents a case study that aims to explore students' interaction with misleading graphs and unpack their mathematical reasoning as they do so to identify patterns that can explain their graph interpretation abilities.

Theoretical Framework

This study is developed on the theories of critical mathematics literacy (Frankenstein, 1994) and graphicacy (Wainer, 1992). While critical mathematics literacy views mathematics as a socio-political tool for identifying and questioning societal injustices (Frankenstein, 2001), graphicacy focuses on understanding and interpreting graphical data (Wainer, 1992). By combining these frameworks, this paper aims to show that proficiency in reading graphs and understanding the data helps individuals grasp socio-political issues and critically evaluate the perspectives represented or omitted in visualisations. Researchers have proposed various frameworks for evaluating an individual's graphical comprehension; this study utilises Curcio's (1987) framework, which assesses graph comprehension through three aspects: reading the data: extracting data from graphs, reading between the data: identifying relationships between variables presented in graphs, and reading beyond the data: making future predictions.

Methodology

This research was conducted on nineteen undergraduate Business Administration students enrolled in a Quantitative Reasoning course in an urban private research university in the North-Eastern Region of the United States. They completed a graph worksheet containing two graphs with mathematical inconsistencies. To investigate students' interaction with misleading graphs, we asked them to complete a worksheet containing graphs with some mathematical inconsistencies. In the first bar graph on federal welfare (Fig. 1. Left) presented by the Republican side of the Senate Budget Committee, the y-axis was truncated, and in the second "job loss by quarter" graph (Fig. 1 Right) extracted from Fox News, the scales along the x-axis and the y-axis were inconsistent. To measure students' ability to comprehend graphs, each graph was accompanied by three questions assessing students' capacity to read the data, read between the data, and read beyond the data (Curcio, 1987). For instance, with the "Job loss" graph, to investigate students' ability to read data we asked them to identify the number of people who lost jobs in September 2008. To measure students' capacity to read between the data, we asked them that "A local news agency claimed that joblessness increased at a constant rate between December 2007 and June 2010. Do you agree with the claim?" Finally, students were prompted to predict future job losses to evaluate their ability to read beyond the data. Students wrote justifications for their answers to help the research team gain insights into their mathematical reasoning. The research team performed open coding (Strauss & Corbin, 2004) to analyse the students' responses and the written justifications.

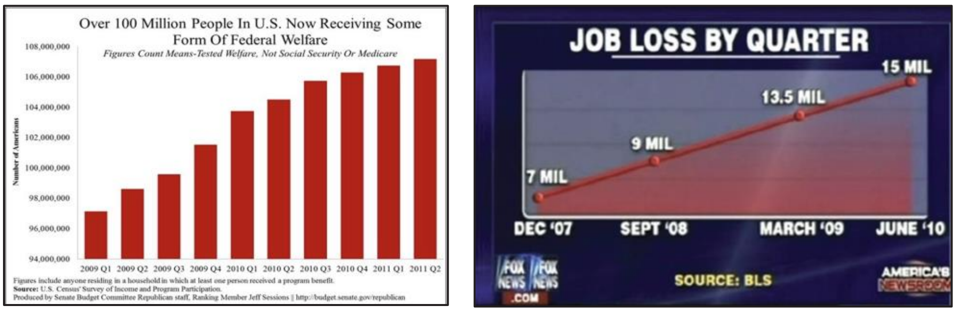

Fig. 1. Left: People in the US receiving Federal welfare. Right: Job loss by Quarter Graph

Findings

Our study offers three primary outcomes. First, while students could generally read the data from both graphs, they struggled with interpreting relationships between the data and making predictions, particularly with the job loss graph. Next, to unpack the reasons behind this challenge, we analysed their written justifications. Many students who failed to identify the misleading nature of the graph relied on its visual appearance, such as the perceived straightness of the line, rather than engaging in deeper mathematical reasoning. In contrast, students who accurately identified that job loss did not increase at a constant rate used more rigorous analytical methods, like calculating slopes and comparing them over time. This pattern was also observed with the federal welfare graph.

Thirdly, when prompted to consider why the newspaper might have presented misleading information, only one student questioned the source's intent, linking it to political motivations. Such understanding aligns with goal of critical mathematics education, where the student has used mathematics as a tool to question the intent of the source producing the graph. But we did not get similar responses from other students.

Conclusion

In today's world of widespread misinformation, being able to analyse graphical data critically is more important than ever. This study looked into why students often struggle to identify misleading graphs, aiming to provide insights that can help reshape how graph literacy is taught in schools. While the research focused on U.S. education, its findings are highly relevant worldwide, especially as data-driven communication becomes essential. The study calls for a global conversation on how to equip the next generation with the skills needed to navigate a data-rich world thoughtfully and critically.

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Building Teacher Discourse on What is Science and Nature of Scientific Knowledge: A Review of Movie 'Ek Doctor Ki Maut'

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This study is a review of the movie 'Ek Doctor Ki Maut' to understand how the movie depicts different aspects of Nature of Science (NOS). Using an integrative approach to understand Nature of Science within the context of scientific inquiry, we identified different episodes from the film and analysed those episodes to develop a teacher discourse on NOS. Findings from our review suggest that through structured questioning and discussions, many important aspects of NOS can be taken up with school teachers by exposing them to different aspects of the Process of Scientific Inquiry (PoSI).

Keywords: Nature of Science, Process of Scientific Inquiry, Scientific Inquiry Contexts, Teacher Professional Development

Introduction

Science teachers are generally expected to have a good understanding of the nature and processes of scientific inquiry and scientific knowledge. However, research studies have found that teachers generally have a poor conception of Nature of Science (Lederman, 1992) and that teachers have several misconceptions about the processes and methods of scientific inquiry (Liang et. al., 2009). So, there is a strong need to have a discourse with teachers around these issues. In this regard, films and documentaries could be good teacher professional development resources that can help teachers develop a more nuanced understanding of the nature of scientific knowledge (NOS) and processes of scientific inquiry (PoSI).

Koehler, Bloom & Binns (2013) argue that films can be good resources to demonstrate, describe and discuss many different aspects of science. Saritas (2020) found that carefully chosen biographical films can have a positive impact on teachers' views about NOS. In this study, we have reviewed the Hindi film 'Ek Doctor Ki Maut' which showcases the work and life of a scientist who is developing a vaccine for Leprosy.

Frameworks and Methods

There have been several studies (Lederman, 1992) to understand the teachers and students' perceptions about the key aspects of NOS. However, in most of these studies, the talk around NOS, that deals with questions about epistemological underpinning of scientific knowledge, is done separate from the larger question of 'what is science'. Understanding 'what is science' requires understanding the processes of scientific inquiry and how these are influenced by social, economical, political and historical contexts. So, there is a need to integrate the NOS understanding within the scientific inquiry and have discourse around NOS within the larger discourse about the processes of scientific inquiry (PoSI).

Schwartz et. al. (2004) found that an explicit discourse on NOS when teachers are exposed to authentic inquiry environments is helpful in promoting the understanding of NOS. Films showcasing the works and lives of scientists could also be useful to expose teachers to authentic science inquiry contexts and help integrate NOS discourse within the discourse on PoSI. Using this integrative framework and methods of discourse and conversation analysis, we have reviewed and analysed the different episodes of Hindi movie 'Ek Doctor Ki Maut (1990)' as a science teacher professional development resource. The main *research questions* guiding our study are:

- What different aspects of the process of scientific inquiry (PoSI) and nature of scientific knowledge (NOS) are presented in the movie 'Ek Doctor Ki Maut'? How does the movie present these different aspects?
- Through selected episodes from the movie, how can we build a teacher discourse on different aspects of PoSI and NOS?

Analysis and Discussion

Film shows the work of Dr Roy who is developing a vaccine for Leprosy. While performing the experiments and doing his study, Dr Roy is engaged in the continuous process of asking questions, reading literature, taking notes and keeping notes in order, repeating experiments, doing discussions with fellow scientists, sharing resources among fellow scientists, etc. This helps understand the complex and nonlinear nature of the process of scientific inquiry.

Though Dr Roy could develop the vaccine but there were many challenges for it to be used successfully. One of the challenges that Dr Roy was facing was toxicity in his vaccine. For many years he kept working to eliminate toxicity from his vaccine. He keeps working and conducting experiments during late nights in the lab set up at his home and there are many interesting arguments between him and his wife.

Dr Roy's wife: सोना नहीं है ? (Won't you sleep?)

Dr Roy: नहीं .. एक बहुत interesting result मिल रहा है, बहुत interesting (I am getting a very interesting result, very interesting)

Dr Roy's wife: result तो तुम्हे पिछले दस सालों से मिल रहा है .. but it all ends up in nothing .. क्यूंकि तुम्ही थोड़ी देर बाद कहोगे के एक न्य सवाल खड़ा हो गया है (you are getting result from last 10 years .. but it all ends up in nothing .. because after some time you only will say that a new question has come up)

Dr Roy's wife seems frustrated at Dr Roy's attitude who keep telling her that he is getting new results but still no end result in his research. The idea of repeated failure of experiments, redesigning, redoing, keep trying and trying, answering new questions that have come up, helps understand the nature of experimentation in science and that empirical evidence is the basis of all scientific knowledge.

In another scene Dr. Roy discusses his experimental process with the journalist Amaulya. Dr Roy says "I tested the vaccine on mice and rhesus monkeys. The results were promising, but we need more data before we can say it will work on humans." This reflects the empirical foundation of scientific research, where conclusions are drawn from systematic observations and experimentation.

Though Dr Roy's aim was to cure leprosy, he found that when the vaccine was given to a sterile monkey, she could get pregnant after the vaccine was administered to her. The result of the side effect of leprosy vaccine to cure sterility among women was purely due to chance. This helps understand the importance of chance in the process of scientific inquiry.

The film does take up several other important aspects of NOS and PoSI like the role of asking questions in doing science, role of evidence and justification in science, science as a collaborative human endeavor, nature of relationship between science and society, science as social and cultural process, role and process of publishing in science, etc.

Through our review and analysis, we have identified different episodes from the film that can be shown to the teachers for discussions around different aspects of NOS and POSI. Our analysis has also led to planning of discussions with teachers around selected episodes through structured questioning. Such a structured approach has been found more useful by researchers (Saritas, 2020) to use films as a resource for teacher professional development. In a next step to our study, we plan to conduct some teacher workshops and understand the impact of the film on teachers' perceptions of NOS.

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ICT-Based Pedagogical Approaches for Teaching Sulbha Sutra Geometry

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Incorporation of ICT in educational practices has revolutionised conventional teaching approaches, offering innovative ways to improve student learning experiences. This study examines the application of ICT-based pedagogical approaches in teaching the geometry of the Sulbha Sutra, an ancient Indian text. The research primarily focuses on identifying the effective ICT tools and resources that can facilitate the comprehension and instruction of Sulbha Sutra geometry. It also highlights the challenges and benefits associated with the intervention of ICT tools in the educational setting. It uses qualitative content analysis, to provide details of the ICT-based pedagogical approach for teaching Sulbha Sutra geometry. The study identified multiple ICT resources that enhance the teaching of Sulbha Sutra geometry, including digital simulations, 3D modeling tools, and interactive application specifically GeoGebra. The findings offer valuable insights into how educational technologies can be effectively utilised to teach traditional mathematical concepts, thus bridging the gap between ancient knowledge and modern pedagogical practices.

Keywords: Indian Knowledge System, ICT, Sulbha Sutra, Geometry, Pedagogy, GeoGebra

Introduction

The Sulbha Sutras, which are part of the Vedangas, are included within the Kalpa Sutras. Four main Sulba Sutras that exist are: Baudhayana, Manava, Katyayana, and Apastamba, alongside several minor ones (Dutta, 2002). "Sulbha" translates to "string, cord, or rope." The primary Sulbha Sutras follow overall similar structures, beginning with sections on arithmetical and geometric constructions and ending with guidelines for building cities, now understood as altars or ritual platforms. Geometrical constructions are made by drawing arcs using various radii and centres with a Sulbha or chord (Price, 2002). Modern mathematical education differs from the traditional knowledge found in the Indian knowledge system. Blending contemporary tools with Indian Knowledge Systems (IKS) concepts, particularly Sulbha sutra, could improve students' understanding of geometry. To foster a well-rounded educational approach, it is crucial to integrate IKS seamlessly into the current educational framework (Vaz, 2024).

Review of the Related Literature

According to Dwivedi (2024), Sulbha Sutras places a strong emphasis on practical problem-solving techniques, experiential learning, and mnemonic methods. Ancient Indian mathematics teaching was multifaceted since it used Sanskrit equations for geometric operations. There is a need to develop structured courses highlighting key aspects of Indian knowledge systems, training educators for effective teaching, and promoting interdisciplinary learning. (Vaz, 2024) Utilising ICT tools like Maxima, GAP, and Euler Math Toolbox for mathematics, enhances problem-solving and conceptual understanding. Hence, there is a need to introduce courses on Indian history, philosophy, arts, and literature. As per Das, (2019) ICT makes it possible to use visual aids like projectors to convey mathematical concepts, which helps students understand geometry and trigonometry more thoroughly. By facilitating the application of theoretical concepts in real-life circumstances, ICT integration in mathematics education helps students prepare themselves for issues they may face in the real world. Through the use of digital resources, simulations, and virtual tools, ICT integration in mathematics education offers dynamic classroom environments that improve student engagement and learning outcomes. Aggarwal & Bal (2020) suggests that ICT tools make mathematics more engaging for students by visualising issues and increasing their interest in the topic. Programs such as Math Mechanics and GeoGebra help in problem-solving and in the creation of geometric figures and improving mental understanding.

Research Gap

According to a review of the literature, there is a research gap regarding the pedagogical practices needed to teach Sulbha Sutra geometry. However, there is a lack of studies examining ICT-based pedagogical approaches for teaching Sulbha Sutra geometry or exploring the challenges and advantages associated with implementing such approaches.

Research Questions

The study aims to address the following research questions:

- To identify the effective ICT tools and resources for teaching Sulbha Sutra geometry.
- To identify the challenges and benefits associated with the intervention of ICT tools in the educational setting.

Methodology

The content analysis method was utilised by the researcher. Relevant passages from the Baudhayana Sulba Sutra were chosen for examination; using accepted translations. Relevant articles and research papers are also used to conclude the results.

Findings and Conclusion

The study identified multiple ICT resources that enhance the teaching of Sulbha Sutra geometry, including digital simulations, 3D modeling tools, and interactive applications specifically GeoGebra. This tool, along with multimedia presentations and virtual learning environments, simplify complex concepts effectively. In Fig 1., the principles of Sulbha Sutra geometry were effectively represented in GeoGebra, enabling accurate visual constructions. For instance, a rectangle ABCD with an area of 7.8 units was modeled. Using $\sqrt{7.8} \approx 2.8$ units, we constructed a square of equal area, demonstrating precise geometric equivalence and validating ancient methodologies through modern tools.

While ICT tools foster critical thinking and active learning, their integration faces significant challenges such as insufficient teacher training, limited technology in underfunded schools, and initial resistance to combining new resources with traditional curricula. However, the benefits, such as interactive experiences, customised learning, and visualisation of abstract concepts, outweigh the difficulties. The study concludes that ICT significantly improves the learning of Sulbha Sutra geometry.

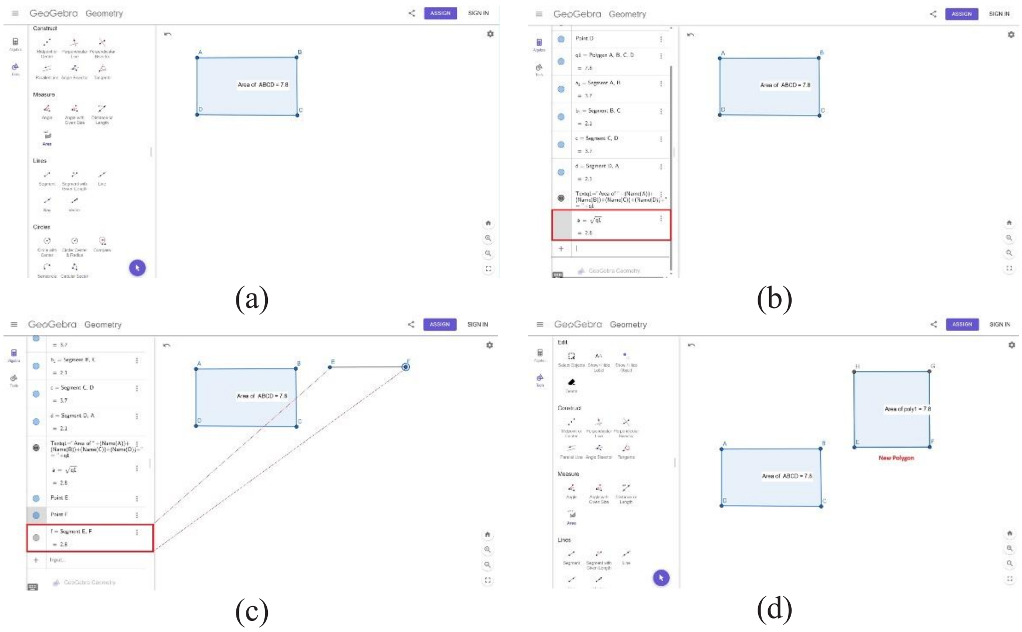

Fig. 1. Construction of a square equivalent to a given rectangle using Sulbha Sutra principles in GeoGebra. Drawing and analysing the rectangle (a), Determining the side length of the equivalent square (b), Constructing the equivalent square (c) and Verification of the construction (d).

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Seeking the Synergy Between Biology and Math Education

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The paper tries to study and challenge the wider perception of the antagonistic relation between biology and mathematics. This antagonism starts at school and thus leaves very little scope for any organic connection to happen later in higher education. The study consists of looking at the school curriculum, specifically the textbook to identify the existing separation between the two disciplines. It also reports some cases where the two disciplines can come together more organically and strengthen the understanding of a topic. The paper argues how biology and mathematics can provide rich context for each other in science education.

Keywords: STEM-Integration, Math-Education, Biology Education, Contextual Learning

Introduction

The emerging global concerns like Covid-19 pandemic and environmental crisis have once again brought in the domain of science as a core foundational discipline in the field of education. Addressing such complex global issues demands an integrated STEM curriculum (Kelley & Knowles, 2016). The need for an integrated STEM curriculum is being widely acknowledged both nationally and internationally (NEP, 2020; Kelley & Knowles, 2016). Thus, the school curriculum shall bring different disciplines of science and math together. On the contrary, we see that the school curriculum creates very rigid boundaries between disciplines. Further, the curriculum brings in science much later compared to mathematics which gets introduced at the elementary level itself.

The National Education Policy (NEP, 2020) emphasises an interdisciplinary approach towards education and flexibility in choosing subjects. While the school curriculum still maintains a hierarchical disciplinary division between subject choices. This can be seen even within the STEM field, with a clear hierarchical distinction maintained between biology (or life sciences) and mathematics (Bialek & Botstein, 2004). In the Indian school system, this gets decided after a student clears their secondary board exam. To have a wholistic science education, it is essential to integrate the different disciplinary practices in an organic way.

Theoretical Framework

Although literature has widely recognised the importance of bringing mathematics to biology often (Abrori, Tejera, & Lavicza, 2024), the converse is not quite true. Mathematics is considered the most abstract discipline in the STEM hierarchy, which demands math educators and researchers to keep looking for meaningful contexts to introduce abstract mathematical concepts. While there is continuous work in the field of math education to bring in realistic context for the introduction of different math concepts like negative numbers, algebra, geometry in school mathematics, some of the contexts are still far-stretched connections to real life. While the importance of quantitative thinking in biology is well recognised (Bialek & Botstein, 2004), seeing biology to provide relevant context for quantitative thinking is yet to be acknowledged. The recognition of the field of biology to provide a meaningful integrated mathematical experience requires more groundwork. And this needs to start at the school itself rather than attempting to fix it at the higher education level.

Research Questions

The study attempts to inquire and address the following research questions:

- How does the current curriculum and the textbook create an antagonism between biology and mathematics?
- How can the different contexts of biology be used in mathematics education?

Methods and findings

The research method adopted for the study is close to qualitative-interpretative method. The data points for the study consist of textbook analysis and case studies. A preliminary analysis of the textbooks followed in most school curriculum in the Indian context suggests a lack of any connection made between the two disciplines. While most teachers rely on such poorly integrated textbooks for students, there are some textbooks and some cases where the context of biology is meaningfully used to bring relevant conceptual ideas of mathematics. For instance, the Bal Vaigyanik book of class-8, has an activity where students are asked to note the length and breadth of different leaves and see the ratio between them (p.50). Such context to discuss the idea of proportionality brings a richer understanding of proportional reasoning and provides a more ecological context for students compared to contexts provided in the conventional math textbooks (Lamon, 1999). Additionally, there are different investigation questions taken up by the CUBE (Collaborative Undergraduate Biology Education) group, where the subject matter of investigation is generally picked up from the immediate surroundings and are studies using quantitative thinking and measurement. Like for example measuring the nail growth through the marked ink strain on the nail over a period, or the number of mango trees flowering in each area during a particular season and seeing the pattern over the time across different areas. Similar integrated approaches to science and math education are achieved through model-based reasoning even with young students (Lehrer & Schauble, 2000).

Thus, the study aims to identify relevant biological contexts which can be used to introduce abstract mathematical ideas, for example the bacterial growth is a very useful context to introduce logarithmic scale.

Conclusion

The study highlights how the base of the divide between math and biology starts at the school itself through the school curriculum which then gets reflected even in the popular perception. The divide thus created at the secondary level cause grave damage for any future integration to happen between the two disciplines. Thus, the study calls for a need to revisit our school curriculum, identify useful contexts, and redesign it in ways that lead to a more integrated, non-hierarchical connection between biology and mathematics. More importantly, where the rich context of biology can be used to teach mathematics.

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Media Literacy and Pseudo-Scientific Beliefs: A Survey Study Among Secondary School Teachers

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Abstract: In the present infodemic era, media resources are becoming responsible for growing pseudoscientific beliefs, especially in academics, where false material is readily available that spreads myths and non-scientific knowledge. It is important for teachers to critically analyse the content, and differentiate between scientific, valid knowledge, and misconception, for which media literacy plays an important role. The need for media literacy to counter pseudoscientific views was highlighted by a previous study that showed a lower ability of teachers to distinguish fact from fiction. Therefore, a co-relational survey was conducted using a standardised five-point Likert scale to determine the level and relationship between media literacy and pseudoscientific beliefs among secondary-level teachers.

Keywords: Media Literacy, Pseudo-Scientific Beliefs, Secondary School Teachers

Introduction

According to Shermer, ‘pseudoscience’ describes theories and arguments not backed by empirical data and goes against accepted scientific principles but utilises scientific jargon to make them seem legitimate (Kızılcık, 2024). Teachers and students are in the age of infodemic where knowledge is readily available and media may often be responsible for disseminating misconceptions and non-scientific knowledge. A media-literate teacher can better grasp how to understand media productions and their impact on individuals (Kızılcık, 2024). ‘Media literacy’ is the ability to access, analyse, evaluate, and transmit messages in different written and unwritten formats (İnceoğlu, 2007). It is a multifaceted capability that allows individuals to receive media messages, interpret critically, and express their thoughts and beliefs (Shibata, 2003). This study is an attempt to bring an argument that media resources propagate pseudoscientific beliefs and bogus science. As a result, teachers must be able to distinguish between media-supported deception and legitimate science. If teachers accept the material without considering its scientific validity, they may be transmitting their knowledge in teaching students with that inclination. Critical skills such as analysis, synthesis, interpretation, inference, problem-solving, explanation, open-mindedness, and self-regulation can distinguish science from pseudoscience (Castelão Lawless, 2002). Thus, it is crucial to understand how teachers respond and analyse media to avoid non-scientific knowledge and to disseminate scientific knowledge.

Research Questions

This study aims to address the following questions:

- What is the level of media literacy and pseudoscientific beliefs among secondary school teachers?

- Is there any correlation between media literacy and pseudoscientific beliefs among secondary school teachers?

Methodology

In this study, a survey is conducted among secondary school teachers who are not part of any media literacy courses earlier. The data is collected through online mode using a Google form. To determine pseudoscientific beliefs, the 'Pseudoscientific Belief Scale' (PBS) developed by Çetinkaya and Taşar (2018) is used. This scale consists of 21 items in a five-point Likert scale format, which is grouped into three factors as follows, pseudo-physical claims, pseudo-predictive claims, and pseudo-medical claims. Similarly, to determine media literacy, the 'Media Literacy Scale' (MLS) developed by Tüzel (2012) is used. This scale comprises 30 items in a five-point Likert scale format, which is grouped into three factors as follows, Confidence, Literacy, and Dependency. The data are analysed using descriptive statistics and correlation through computer software like Microsoft Excel and IBM SPSS.

Findings

The data are received from 50 secondary school teachers from both government and private schools of Uttar Pradesh and Uttarakhand states, while a few are from Delhi and surrounding states. The teachers are from a mixed group with experience ranging from 1 year to 20 years spread in the age group ranging from 20 to 50 years, teaching different school subjects, not limited to science subjects. The descriptive statistics presented in Table 1, show a moderate level of pseudo-scientific belief with the mean distribution spread over with varied responses slightly leaning towards left in the PBS Scale, while the MLS scale also shows a moderate level of confidence, literacy, and a high dependency on media for information with the mean distribution spread over with varied responses slightly leaning towards left in the MLS Scale.

Scale	Factor	Mean	Level	Std. Deviation	Skewness	Kurtosis
PBS Scale	S1-F1: Pseudo-physical claims	2.9344	M	.42802	-1.112	.256
	S1-F2: Pseudo-predictive claims	3.0833	M	.50973	.043	-.653
	S1-F3: Pseudo-medical claims	2.9300	M	.71479	.814	-.727
MLS Scale	S2-F1: Confidence	3.2245	M	.31037	-.681	.237
	S2-F2: Literacy	3.0357	M	.59908	-.232	-2.565
	S2-F3: Dependency	3.4275	H	.22467	.133	-1.410

Table 1. Descriptive statistics of scales

Though the spread of scores indicates the variation in the responses, the relationship between the pseudo-scientific beliefs and media literacy is still unknown. To find if there is any correlation between media literacy and pseudoscientific beliefs among secondary school teachers, the data is analysed using the Pearson Correlation coefficient, considering different factors of both the scales mentioned above. The results in Table 2 indicate a strong positive relationship among the factors of the PBS scale, which means that if an individual holds pseudo-scientific belief in one factor, they tend to hold the belief in other factors too. The other values indicate a weak or negligible correlation with values close to 0 and statistically not significant between the factors of the PBS scale and MLS scale. This means the factors within the MLS scale are not interdependent and also the factors of the PBS scale do not show any dependency on the factors of the MLS scale. However, the values in Table 1 and Table 2 show that secondary school teachers have a moderate level of pseudo-scientific ideas and a high dependency on media for information and knowledge.

	Scales and Factors	S1F1	S1F2	S1F3	S2F1	S2F2
S1F2	Pearson Correlation Sig. (2-tailed)	.804 .000				
S1F3	Pearson Correlation Sig. (2-tailed)	.761 .000	.741 .000			
S2F1	Pearson Correlation Sig. (2-tailed)	-.026 .855	-.037 .794	.003 .985		
S2F2	Pearson Correlation Sig. (2-tailed)	.028 .847	-.174 .223	.007 .964	.178 .212	
S2F3	Pearson Correlation Sig. (2-tailed)	-.102 .477	-.140 .326	-.199 .162	.296 .035	-.251 .075

Table 2. Pearson correlation coefficients of factors.

Conclusion

The present study reveals a high dependency on media. Nowadays, people spend more time online since digital technology is getting integrated extensively into our daily and academic lives, both formally and informally. The prevalence of pseudo-scientific beliefs can persist even in situations when media literacy is high. Though the teachers mark the moderate level of pseudo-scientific beliefs and media literacy, the spread of opinions informs the need for awareness on this issue. By providing correct science communication in the media, the problem can be effectively remedied.

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Note: The names are listed in alphabetical order.

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Meet our Sponsors

epiSTEME10 is supported by the Tata Institute of Fundamental Research (TIFR) and Department of Atomic Energy (DAE), and jointly organised with the Mathematics Teachers' Association (MTA (I)), Indian Association for Physics Teachers (IAPT), Association for Chemistry Teachers (ACT) and Association for Teachers in Biological Sciences (ATBS). We are grateful for their sponsorship and support.

Tata Institute of Fundamental Research (TIFR)

https://www.tifr.res.in/

TIFR is a National Centre of the Government of India, under the umbrella of the Department of Atomic Energy, as well as a Deemed University awarding degrees for master's and doctoral programmes. The Institute was founded in 1945 with support from the Sir Dorabji Tata Trust under the vision of Dr. Homi Bhabha. TIFR carries out basic research in physics, chemistry, biology, mathematics, computer science and science education. TIFR's main campus is located in Mumbai, with centres at Bengaluru, Hyderabad, Mumbai, and Pune and field stations across the country.

The mission of TIFR comprises the following:

- to set up and conduct top quality research in the country, in the areas of natural sciences, mathematics, computer science and science education;
- to set up state-of-the-art facilities incorporating advanced scientific technology;
- to foster new technologies arising from fundamental science, and incubate their early development until they reach maturity and can be managed by a separate, independent institution;
- to bring together outstanding scientists and mathematicians, provide them with world-class research facilities, and create a vibrant research atmosphere;
- to nurture and train the young scientific talent of the country, expose them to state-of-the-art research, and make them independent researchers on par with the best in the world;
- to contribute to the scientific development of the country by participating in the development of science curricula at all levels;
- to disseminate the knowledge of science and mathematics to the society in general through outreach activities, and thereby build up the scientific temper and a scientific outlook among the public.

Research at TIFR

TIFR is internationally renowned for its cutting-edge research activities in physics, mathematics, biology, chemistry, computer science, and science education, as well as in several interdisciplinary areas.

In physics, it has contributed significantly to areas like particle physics, condensed matter physics, and astrophysics. The theoretical physics group has made important contributions in areas like quantum field theory, string theory and theoretical astrophysics. The high energy physics group is actively involved in large global collaborations at international particle collider facilities. TIFR is a leader in astronomy and astrophysics, operating the Giant Metrewave Radio Telescope (GMRT), the world's largest and most sensitive radio-telescope array at low frequencies, and also space-based observatories. The condensed matter physics and materials science department is known for its work in the areas of magnetism and superconductivity, semiconductors, nanoelectronics, and plasmonics, optical and electron spectroscopy, quantum computing, and soft-matter physics. Research in nuclear and atomic physics spans a range of activities from experimental studies in nuclear structure, conducted at the BARC-TIFR Pelletron heavy-ion accelerator, to ultra-high intensity light-matter interactions. TIFR is developing the country's first petawatt class laser facility at its Hyderabad campus.

In mathematics, TIFR focuses on pure and applied mathematics, and has made groundbreaking contributions in areas like algebraic geometry, number theory, and topology. The School of Technology and Computer Science pursues innovation in algorithms, quantum computing, and information systems. In the area of biological sciences, research at the TIFR main campus, TIFR Hyderabad and the National Centre for Biological Sciences, explores molecular and cellular biology, structural biology, and neuroscience, contributing to a deeper understanding of life processes, with several interdisciplinary initiatives that link biology with physics and computational methods.

TIFR also plays a crucial role in science education and public outreach, nurturing young talent through PhD programs, workshops, and initiatives to promote scientific curiosity nationwide. The Homi Bhabha Centre for Science Education (HBCSE), Mumbai is the premier institution in the country for research and development in science, technology and mathematics education. It is India's nodal center for Olympiad programmes in mathematics, physics, chemistry, biology and astronomy. HBCSE aims to promote excellence and equity in science and mathematics education from primary school to introductory college levels and to encourage the growth of scientific literacy in the country.

Dept. of Astronomy and Astrophysics- http://www.tifr.res.in/~daa/
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Dept. of High Energy Physics- http://www.tifr.res.in/~dhep/
Dept. of Nuclear and Atomic Physics- http://www.tifr.res.in/~dnap/
Dept. of Theoretical Physics- http://theory.tifr.res.in/
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Department of Chemical Sciences- http://www.tifr.res.in/~dcs/
Department of Biological Sciences- http://www.tifr.res.in/~dbs
School of Technology and Computer Science- https://www.tcs.tifr.res.in/web/
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National Centre for Biological Sciences- https://www.ncbs.res.in/
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International Centre for Theoretical Studies in Bengaluru- https://www.icts.res.in/
Centre for Applicable Mathematics, Bengaluru- https://www.math.tifrbng.res.in/
National Centre for Mathematics, Mumbai; A joint centre of IIT Bombay & TIFR, Mumbai-
https://www.atmschools.org/

Department of Atomic Energy

https://dae.gov.in/

The Department of Atomic Energy (DAE) was set up under the direct charge of the Prime Minister through a Presidential Order on August 3, 1954. As per this order, all businesses of the Government of India, related to Atomic Energy and to the functions of the Central Government under the Atomic Energy Act, 1948 were directed to be transacted in the Department of Atomic Energy. DAE encompasses all the areas related to power and non-power applications of atomic energy. DAE comprises 6 research centres, 3 industrial organisations, 5 public sector undertakings, 3 service organisations, and 11 grant-in-aid institutes of international repute engaged in research in basic and applied sciences, cancer research and education. It also has under its aegis, 2 boards for promoting and funding extramural research in nuclear and allied fields and mathematics. DAE is at the fore-front of research and development, leveraged by a strong synergy between R&D and technology development in a number of core disciplines of national and international importance. DAE continued to develop and deploy spin-off technologies for societal applications like advanced seed and crop varieties, food preservation, clean water, urban waste management, etc.

Vision

The vision of the Department of Atomic Energy is to empower India through technology, creation of more wealth and providing better quality of life to its citizens. This is to be achieved by making India energy independent, contributing to provision of sufficient, safe and nutritious food and better health care to our people through development and deployment of nuclear and radiation technologies and their applications.

Mission

- Increasing share of nuclear power through deployment of indigenous and other proven technologies, along with development of fast breeder reactors and thorium reactors with associated fuel cycle facilities.
- Building and operation of research reactors for production of radioisotopes and carrying out radiation technology applications in the field of medicine, agriculture and industry, cancer care, water related technologies, waste management etc.
- Developing advanced technologies such as accelerators, lasers, supercomputers, advanced materials and instrumentation, and encouraging transfer of technology to industry.
- Support to basic research in nuclear energy and related frontier areas of science; interaction with universities and academic institutions, Support to research and development projects having a bearing in DAE’s programmes, and international cooperation in related advanced areas of research, and
- Contribution to national security.

Mathematics Teachers' Association (India)

https://www.mtai.org.in/

The Mathematics Teachers' Association (MTA) was founded on 20 March 2018 at the Homi Bhabha Centre for Science Education (HBCSE), Mumbai. Its establishment was driven by the vision of the founding members to create a platform that unites teachers, educators, and mathematicians in a collaborative effort to advance the quality of mathematics education at all levels. The association aims to foster a deeper interest in mathematics among students, nurture mathematical talent, and promote excellence in the teaching and learning of mathematics across the nation.

The objectives of MTA include:

- Developing and promoting learning materials and teaching strategies that make mathematics enjoyable and accessible.
- Organising conferences, seminars, workshops, and reorientation programmes for teachers.
- Supporting Olympiad programmes through examinations and training camps for students and teachers.
- Raising public awareness and interest in mathematics through diverse media platforms.
- Publishing periodicals focused on mathematics teaching, learning, and professional development for mathematics teachers and educators.
- Collaborating with national and international organisations with similar goals.
- Pursuing other activities aligned with the objectives of MTA.

Activities of the Association

The association engages in a diverse range of initiatives aimed at fostering knowledge exchange among mathematics educators and education researchers. These activities include national and regional conferences, collaborative workshops, development of a bulletin, study groups, and the organisation of the Indian Olympiad Qualifier Examination, among others.

National Conferences

The inaugural MTA conference was held from January 3–5, 2019, coinciding with the 188th birth anniversary of Savitribai Phule, a trailblazer in universal education. Hosted at HBCSE, Mumbai, the conference received an enthusiastic response from mathematics teachers, laying a strong foundation for subsequent annual conferences on diverse themes. Since its inception, the association has organised four national conferences, which transitioned to an online format due to the COVID-19 pandemic.

The first conference focused on bridging school and college-level mathematics through technology. The second, held virtually, addressed Mathematics Education during the COVID-19 pandemic. The third explored "Rethinking Mathematics Education During the Pandemic," and the fourth focused on enhancing teacher preparedness for mathematics teaching and learning.

Regional Conferences

Since 2023, the association has expanded its outreach by organising regional conferences in collaboration with local organisations, furthering its mission to improve mathematics education across India. The inaugural regional conference for the Western Region was held in January 2024, in partnership with SCERT and the Department of Higher Education, Goa. The second regional conference for the Southern Region took place in September 2024, organised in collaboration with CUSAT, Kochi.

Blackboard: A Bulletin

The MTA introduced its bulletin, Blackboard, under the editorship of Prof. B. Sury, with support from an Editorial Board. The inaugural issue was launched at the first MTA conference, and six subsequent issues have been published, all available on the MTA website. The bulletin explores a variety of themes, including the history of mathematics, connections between undergraduate and school-level mathematics, and novel insights or derivations in mathematical ideas.

IOQM: Indian Olympiad Qualifier in Mathematics – Examination

One of the most significant activities undertaken by the Mathematics Teachers' Association (MTA) is the organisation of the Indian Olympiad Qualifier in Mathematics (IOQM), previously known as the Pre-Regional Mathematical Olympiad (PRMO) prior to the COVID-19 pandemic. Conducted in collaboration with the Homi Bhabha Centre for Science Education (HBCSE), this examination serves as the first stage in the rigorous selection process for India's participation in the prestigious International Mathematical Olympiad (IMO).

Other Activities and Future Plans

In addition to its flagship initiatives, the Mathematics Teachers' Association (MTA) collaborates annually with Azim Premji University to organise a conference focused on teaching undergraduate mathematics. The association also conducts various workshops on themes such as mathematics teacher education, logical reasoning, and problem-solving, aimed at enhancing professional capacity in these areas.

Since the previous year, MTA has introduced study groups dedicated to exploring and applying mathematics education literature, fostering scholarly engagement among educators and researchers. Looking ahead, MTA plans to establish regional nodes to develop activities tailored to the specific needs and contexts of different regions, further advancing its mission to improve mathematics education across India.

Note contributed by: Shweta Naik, Aaloka Kanhere, K Subramaniam & R Ramanujam on behalf of MTA. They extend their heartfelt gratitude to all members of the association, executive council and the institutional collaborators for their invaluable contributions to the development and success of various events.

Indian Association of Physics Teachers

www.indapt.org.in

The Indian Association of Physics Teachers (IAPT) is a voluntary organisation of physics teachers/researchers and other stakeholders with a standing of almost four decades was established in 1984. We are interested in the dissemination of scientific knowledge, promotion of scientific temper and culture with a focus on improvement of quality of physics education at all levels as laid down in our constitution: "To upgrade the level of teaching and teachers of physics and related areas at all levels to pool and mobilise the talents and resources of teachers in the national perspective." We are open to collaborations, sharing and research in Physics education and Science education in general.

With these stated objectives, IAPT organises multiple activities such as - seminars, conferences, examinations, Physics Stage Shows, laboratory workshops and competitions, among others, both for teachers and students. IAPT is a democratic body with office bearers elected every three years and frames policies and programmes in a consensual mode. To achieve efficient outreach, it has demarcated nation into over 30 regions with an autonomous Regional Councils (RCs) to reach every corner of the country to promote our objectives. With almost ten thousand life members across the nation and a few hundred in the Indian diaspora abroad.

All IAPT work is voluntary – members do not expect any remuneration or honorarium for any work of IAPT. It is the largest voluntary body of Physics/science teachers, from schools, colleges and universities, working at the grassroots level in the country. Our pledge is Members will not ask for any privilege, but will rather search for ways in which they can best serve the society. The first meeting of the group was held in IIT Kanpur in 1984. Since then, IAPT is a Work in Progress to achieve its objective with clear goals and achievements.

IAPT has served its stake holders with distinction finding echo of its impact across India and beyond its borders. It prides in voluntary participation by its members to reach out a triad of stakeholders: Students, Teachers and community. Association believes in innovation, sharing and empowerment through our focus subject Physics which has been a fountainhead of many futuristic disciplines and technologies. We are open to new ideas and their implementation from scientific community, common man and our stakeholders.

Some of our flagship activities of IAPT and its members are:

- **IAPT Monthly Bulletin:** A monthly journal of Education in Physics and Related Areas. The Bulletin is being published since 1984 without any break. All the previous issues of the bulletin are available on our website < indapt.org.in >
- **National Standard Examinations NSEs and NSEJS:** National Standard Examination in Physics, Chemistry, Biology, Astronomy & National Standard Examination in Junior Science are the only examinations that lead to participation of Indian Students in the

National & International Science Olympiads. No other examination is authorised for this purpose.

- **National Graduate Physics Examination [NGPE]:** This is the yearly event of IAPT for the students studying in B. Sc. classes. The top five students get Gold Medals and a cash prize of Rs. 20,000/- each.
- **National Anveshika Network of India [NANI]:** National Anveshika Network of India is a flagship programme of IAPT which has been nurtured consistently with a unique aim of reaching the students of schools, colleges and universities. Anveshika is an effort to make Physics education more innovative and enjoyable.
- **National Anveshika Experimental Skill Test [NAEST**]: NANI conducts this unique experimental skill test in physics annually with the help of its network of 30 Anveshikas all over India. The test is conducted in two categories: Junior (class 9/10/11/12 from any State Board / Central Board of India) and Senior (B. Sc./M. Sc. from any affiliated colleges / Universities of India.)
- **National Competitions on Innovative Experiments in Physics [NCIEP]:** This competition is being held since 2003, to encourage Physics teachers, students and Physics educators to conceive and set up original innovative experiments in Physics.
- **National Competition in Computational Physics [NCICP]:** This competition on Software-Based Physics Experiments, is held for the three categories – 1. School 2. UG Section 3. PG Section. Each category has two sub-categories: (A) Students and (B) Teachers.
- **Annual National Students Symposium in Physics [NSSP]:** IAPT has instituted the Annual National Student Symposium in Physics in order to foster innovation and creativity among young students. The yearly series started in the year 2013 in collaboration with the Department of Physics, Panjab University, Chandigarh. The symposium provides a national forum for young students to present their new ideas and innovative work at an early stage of academic career.
- The IAPT awards include the Annual Deenbandhu Sahu Memorial UG Physics Teacher's Award for exceptional contributions to undergraduate physics teaching, the RC Exemplar Awards for top RCs/subRCs, and the Annual BL Saraf and HS Hans Medals for distinguished services to IAPT members. These awards recognise excellence in physics teaching and service within IAPT-affiliated institutions.
- The IAPT organises several annual events, including the National Competition on Essay Writing in Physics (NCEWP) for teachers and students, the National Photo Essay Competition in Physics (NPECP), the Indian National Young Physicists Tournament (INYPT), and the Annual IAPT Convention in collaboration with Regional Councils across India.
- IAPT also handles PARYAS, a Student Journal of Physics; and the Monthly Journal of Physics Education.

For becoming member of IAPT visit our website www.indapt,org.in and sign up. You will get free e-bulletin of IAPT and notifications via e-mail of various events, workshops, webinars, IAPT online classroom.

Association of Chemistry Teachers (India)

www.associationofchemistryteachers.org/

The Association of Chemistry Teachers (ACT) was formed in 2000 to serve as an apex national body of Chemistry educators to promote excellence in Chemistry Education. The idea of formulating ACT was conceptualised by Homi Bhabha Centre for Science Education (TIFR), Mumbai which has always been a pillar of great strength and support to the Association. The Association brings together on a common platform higher secondary school teachers, college and university teachers, scientists and researchers from industry for organising subjected related activities.

Prime Objectives of ACT

- To advance chemistry education in the country by means of curriculum development and innovations in teaching and evaluation methodologies
- To forge a vibrant synergistic relationship between academia, industry and research centres for mutual benefit
- To collaborate with international chemistry organisations and chemistry teachers' associations for organisation of joint programmes
- To organise training workshops, conferences and symposia in different parts of the country including an annual National Convention of Chemistry Teachers (NCCT).
- To explore and nurture talent in Chemistry with special reference to the Indian National and International Chemistry Olympiads

Activities of ACT

- National Convention of Chemistry Teachers (NCCT) held annually in different parts of the country.
- Organisation of subject- related activities like international and national conferences, symposia and training workshops on "Designing Innovative Questions", Research Convention and Concept Test in Chemistry for B.Sc. students
- Celebration of National Chemistry Day on December 10 and National Science Day on February 28 in schools and colleges.
- ACT Research Convention- a series of online lectures on various aspects of Chemistry Research
- Triannual ACT Newsletter which can be accessed on the ACT website.
- ACT is deeply involved with IUPAC in organising the international Global Women's Breakfast (GWB) in February every year. It is a matter of pride that for the past 4 years, India has had the maximum number of entries among the participating nations.

Involvement in Chemistry Olympiad Programme

ACT plays an important role in the organisation of the National Standard Examination in Chemistry (NSEC), the first stage examination of the Indian National and International Chemistry Olympiads.

ACT Awards

ACT has instituted 9 awards to recognise the distinguished Chemistry teachers of the country for their outstanding contributions to Chemistry Teaching and Research.

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Regn. No. Maharashtra Government, Mumbai 922,2010 GBBSD dated 08-04-2010

The Association of Teachers in Biological Sciences (ATBS)

www.atbs.in/

The umbrella of Biological Sciences today has spread far and wide. It has basic disciplines like Plant Sciences (Botany), Animal Sciences (Zoology) and Microbial Sciences (Microbiology) as well as applied sciences such as Agriculture, Horticulture, Medicine, Veterinary Science, Environment Science, Pharmacy, Biotechnology, etc. each with further specialisations. The Association of Teachers in Biological Sciences (ATBS) aims to provide a common platform for teachers to share their experiences, expertise and concerns with others for the betterment of teaching and learning biology.

The challenges like designing the syllabi such that there is proper weightage given to the fundamental principles of life while avoiding an overlap with the syllabi of other sister disciplines, teaching interdisciplinary topics, sharing the advancements in knowledge and skills in sister disciplines can be discussed effectively through such a common platform.

The Association of Teachers in Biological Sciences (ATBS) is a voluntary organisation, registered as a non-profit association with a defined constitution. ATBS was founded in the year 2005-2006 with an objective of “Elevating the quality of teaching and learning Biological Sciences- both, inside and outside the educational systems, through concerted efforts”. So as to achieve this, ATBS has been organising training programmes, workshops, seminars, conferences and colloquiums for teachers and exposure camps, guidance camps as well as various competitions for the students. To encourage research, ATBS organises at least one annual conference in which the best oral and poster presentation in the categories of teachers and students are awarded prizes.

The members of ATBS have undertaken to work for the society at large and particularly students as a service to our beloved country. ATBS works closely with the Biology Cell of HBCSE in selection and training the members of the Indian team to participate in the International Biology Olympiads. The members of ATBS are encouraged to organise and/or work as resource persons in various academic programmes like NIUS, INSPIRE, IRIS, VIPNET, IISF, JIGYASA, SWAYAM and also the Incubation Centers to provide opportunities to the students to showcase their talents and skills.

ATBS has collaborated with and has MoUs with several Institutions and Organisations for organising a variety of programmes beneficial to the students and teachers in the Biological Sciences. The Association is committed to help the teachers and students in performing well in various national and state level competitive tests.

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End Notes

1. The symbol (*) denotes corresponding authors.

2. The symbol (#) denotes co-first authors.

3. Kindly note that the abstracts (text and figures/tables) are published exactly as submitted, with only formatting and editorial edits applied, and no further corrections made.

4. The articles have gone through a double-blind peer review process. The publisher is not responsible for the accuracy or reliability of the data, statements, or conclusions in the articles published.

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