1. Introduction

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The epiSTEME Reviews Volume 4 is an outcome of the talks reviewing the recent research and trends in science, technology, and mathematics education (STME) presented at the epiSTEME 4 conference held in January 2011 at the Homi Bhabha Centre for Science Education, Mumbai, India. The name epiSTEME connotes, at one level, a systematic study of knowledge, while as an acronym it suggests a meta-view of science, technology and mathematics education. The epiSTEME is *a biennial conference series to review research in Science, Technology and Mathematics Education.*

The epiSTEME conferences are unique as they bring together researchers, educationists, students, teachers and activists working in the area of science, technology and mathematics education for an interdisciplinary exchange. In investigating educational issues related to science, technology and mathematics one finds themes originating in philosophy, cognition, history and socio-cultural studies. The epiSTEME series of conferences build on these foundational themes and are organized biennially by the Homi Bhabha Centre for Science Education, Tata Institute of Fundamental Research, Mumbai, India. The first epiSTEME conference, epiSTEME 1 was organized in Goa in December 2004. Subsequently, the conferences in the series have been organized in Mumbai at the HBCSE, in 2007, 2009 and 2011.

The Fourth Conference – epiSTEME 4

Conference epiSTEME 4 was held from January 5 to 9, 2011 at Homi Bhabha Centre for Science Education in Mumbai. The conference had three broad strands around which papers were presented: *(i) Historical, Philosophical and Socio-Cultural Studies of STM – Implications for Education; (ii) Cognitive and Affective Studies of STME (iii) Curriculum and Pedagogical Studies in STME*. The

conference also had review talks, poster presentations and a panel discussion woven around the three strands.

The ten review talks and the keynote address were delivered by eminent speakers. The conference format does not encourage parallel sessions so as to facilitate an interdisciplinary exchange among the STME participants. The conference proceedings which include extended abstracts of the review talks and full papers of the oral presentations and posters is available at: http://episteme4.hbcse.tifr.res.in/proceedings.

The epiSTEME 4 conference was attended by 170 participants – 65 foreign, 56 Indian and 49 HBCSE as seen in Figure 1. The participants of conference epiSTEME 4 represented 17 countries, namely, *Australia, Canada, India, Japan, Lebanon, Malawi, Mauritius, Nigeria, Philippines, Romania, Rwanda, South Africa, Sri Lanka, the Netherlands, Trinidad, UK, USA*. These participants were not all presenters as the conference also provided opportunity for people to be a part of the conference without making presentations. The conference received 102 submissions of which 33 were from non-Indian participants and 69 were Indian submissions. All the submissions underwent a blind review process, and each was reviewed by three reviewers. Based on the reviewers decisions, 72 submissions were accepted (29 foreign and 43 Indian) and 30 submissions were rejected (4 foreign and 26 Indian). Of these 72, there were 64 registrations (23 foreign, 31 Indian, and 10 HBCSE). And of these 64 registrations, 43 were for oral presentations and 21 were for poster presentations.

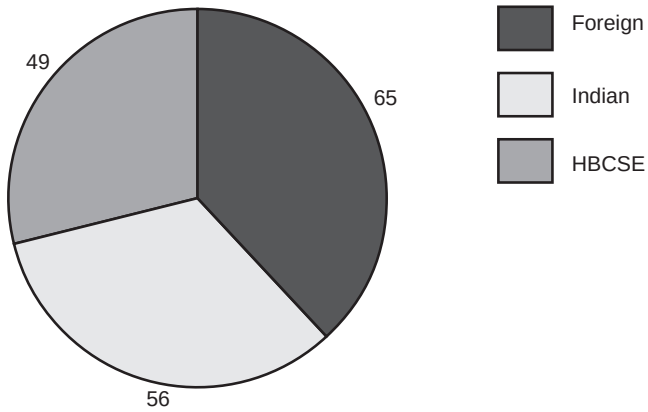

Figure 1: **The total number of participants at epiSTEME 4 conference.**

As depicted in Table 1, of the registrations, overall, Strand 3, *Curriculum and Pedagogical Studies in STME*, received the maximum submissions (29), followed by Strand 2, *Cognitive and Affective*

Studies of STME (23) and Strand 1, *Historical, Philosophical and Socio-Cultural Studies of STM – Implications for Education;* which received the least submissions (12).

Table 1: **Distribution of papers according to strands.**

Strands / Papers	Foreign	Indian	HBCSE	Total (64)
Strand I – Historical, Philosophical and Socio-Cultural Studies of STM – Implications for Education;	5	6	1	12
Strand II – Cognitive and Affective Studies of STME	7	9	7	23
Strand III – Curriculum and Pedagogical Studies in STME	11	16	2	29
Total	23	31	10	64

Figure 2 depicts a geographical distribution of the participants. As the conference was in India, most participants (112) were from the Asia-Pacific region, followed by the USA (39), Africa (11) and Europe (8).

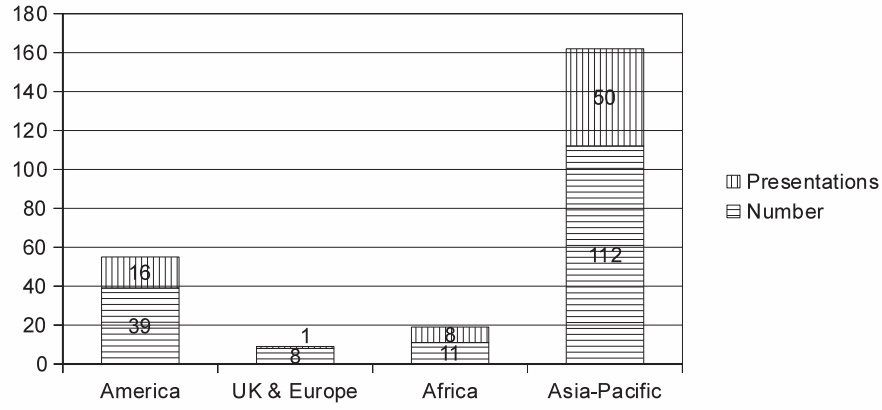

Figure 2: **Distribution of number of participants and presentations (papers, posters).**

The epiSTEME 4 conference received financial support from HBCSE, the Board of Research in Natural Sciences (BRNS), the Department of Science and Technology (DST) and the Central Bank of India. More information about the epiSTEME 4 conference is available on its website: http://episteme4.hbcse.tifr.res.in

Related Workshops and Panel Discussion

During epiSTEME 4, pre and post conference seminars and workshops were also organized. A public talk was delivered by Helen Longino (Stanford University, USA) on *'Feminist Science Studies'*. According to Longino, feminist science studies in the West emerged initially from three concerns: the paucity of women in scientific fields, the persistent use of putative biological considerations to justify gender inequality, and the lack of attention to women's issues in health and social sciences research. The talk gave an overview of the emergence of feminist science studies in the West in the last 25 years, and the different models of knowledge these studies draw on, the different impacts of feminist analysis in the various fields of science, and the different kinds of challenges to feminist intervention posed by the different scientific disciplines.

A pre-conference workshop on *'Learning Environment and Teacher Interpersonal Behavior'* was delivered by Rekha Koul (Curtin University, Australia). The workshop focused on student and teacher interpersonal behavior and its significance to students' academic achievement. A questionnaire on teacher interaction (QTI) that has been used to study teacher interpersonal behavior was discussed in the workshop and a CD was provided to all participants with copies of the QTI instrument, profile drawing program and few useful research papers describing development and use of QTI.

A post-conference workshop spanning two days was jointly presented by David Barlex and Marion Rutland (Brunel University, UK) to focus attention on *'Design and Technology for Education'*. The participants attending the workshop had the opportunity to tackle two 'design and make' assignments. The first task was based on the Nuffield primary solutions unit *'How will your roly poly move?'* The task was about making a simple push-along toy (a roly poly) that provides amusement in both its appearance and the way it moves. The second task was also based on the Nuffield primary solutions unit *'Should your creature be fierce or friendly?'* which was to design and make a creature to welcome visitors to, or deter intruders from, the classroom. Participants presented their work and discussed how such activities could be implemented in their own settings. The public talk and workshops were attended by HBCSE faculty and graduate students as well as teachers and feminist scholars from different parts of Mumbai as well as a few participants of epiSTEME 4.

The panel discussion at the conference was held to disseminate information about a project titled '*Science Education for Diversity*', which involves six partner countries, namely the UK which is leading the project and, India, Lebanon, Malaysia, Turkey and the Netherlands. The Homi Bhabha Centre is a part of the project and represents the Indian contribution. In the panel discussion, partners from UK, India and the Netherlands presented the details of the project, the work already completed and the future plans. Chitra Natarajan, Beena Choksi and Sugra Chunawala (India) presented details of the documentary analysis regarding policies addressing diversity in the context of science education in the six partner countries. Nasser Mansour and Alan Morgan (UK) presented details of the theoretical framework to be adopted for intervention and Michiel Eijck (the Netherlands) discussed the data collection through questionniares and interviews of students and teachers in the partner countries.

Strand 1: Historical, Philosophical and Socio-Cultural Studies of STM: Implications for Education

This strand focusing on the issues related to history and philosophy of science, science and technology studies, and socio-cultural aspects of STME had three review speaker, *Helen Longino, Masakata Ogawa* and *Susantha Goonatilake.*

Helen Longino in her paper described two contrasting *ways of thinking* about the social nature of scientific knowledge that has emerged over the last two decades. She labeled these as contingent and constitutive approaches. The contingent approach holds that the sociality of science is a feature of the way the sciences are currently organized. She elaborates this approach, by using Philip Kitcher's ideal of well ordered science as developed in his 2001 book, *Science, Truth, and Democracy*. The constitutive approach is represented as critical contextual empiricism in her book, *The Fate of Knowledge (2002)*. According to Longino, certain conditions are essential for effective critical discourse, these being, the provision of venues, uptake of criticism, public standards, equality, diversity and inclusion and openness to other perspectives. Longino in her paper, recommends three aspects of research; *feminist interventions in the sciences, risk assessment, and the privatization of knowledge,* whereby the contingent and constitutive sociality approach can provide different perspectives.

Masakata Ogawa's talk focused on multi-science perspectives through reflections from Japan's experiences. The paper highlights the issue of an ideal science education enterprise for non-western learners. Ogawa introduced the audience to the Japanese elementary science program – *Rika* which is an amalgamation of Western modern science and Japanese indigenous knowledge. The unique characteristics of *Rika* were mentioned as being observation based, experiment based, helping to acquire problem-solving abilities, understanding natural phenomenon, acquiring scientific ways of thinking, inculcating a feeling of love for nature and leading to communing with nature. Ogawa stressed that most of these characteristics paralleled the features of education in Western modern science, while the last two characteristics of communing and loving nature are unique to the Japanese education system. The paper presented a brief overview of research trends in cultural studies in science education, followed by the author's personal reflection on the ideas and nature of elementary *Rika* and loving *Shizen* (nature). The paper provides an extensive description of several aspects of elementary Rika; its objectives, its origins, followed by some episodes from Rika classes. The implications of *'education of indigenous science'* through a model for deciphering nature of contemporary societies to contemporary science education is presented.

Susantha Goonatilake focused on the ongoing developments in science and technology that transform the basis of our physical and mental being. Synthetic biology is developed to produce artificial life systems using the same molecular basis as of living systems. Further he elaborated on how humans would inhabit artificially constructed realities. In the present era, the presence of human-like robots are more functional than the earlier mechanical robots. The paper talks of how we are constructed and reconstructed, from new foundational developments that transform our body, mind and our environment, and this would challenge the existing ethical systems. The paper draws parallels with the Buddhist philosophy where body, mind and the environment is being continuously constructed and reconstructed.

Strand 2: Cognitive and Affective Studies

Strand 2 encompassed themes that dealt with cognitive and affective aspects of STME and included sub-themes like Visuo-spatial thinking, Knowledge Representation, Language and Learning, Problem Solving and Learning and Reasoning. The strand featured four review speakers namely, *Jonathan Osborne, K. Subramaniam, Nora Newcombe* and *Mamokgethi Setati.* However, as we did not receive the paper by Setati, this strand like strand 1 has only three papers.

Jonathan Osborne's talk presented the three fundamental ironies existing in science education namely; school science being dominated by training vis-a-vis education, faith in intrinsic values of science, and an absence of critique. He put forward the role of argumentation for critical review and acknowledged its importance in the construction of knowledge. Knowledge according to Osborne is of three types; *scientific knowledge, procedural knowledge,* and *epistemic knowledge.* The latter two forms, Osborne argued are essential for understanding of science. With the help of examples, he illustrated, how knowing what is right is also depended on knowing what is wrong and a critical discussion can be embarked upon by elimination of false ideas rather than a deductive process of establishing what is right. Osborne introduced this approach by using Bayesian form of reasoning; a probabilistic system describing the certainty of knowledge. He has put forward Bayesian inferencing as a model of scientific reasoning further providing rationale for the role of argumentation and critique in science.

K. Subramaniam reviews research on the learning of fractions, multiplicative reasoning and rational numbers. The review has addressed the research on learning of fractions in the past, followed by present trends and argues for integrating research findings into curriculum designing. He emphasizes the teaching and learning of fractions as being of pedagogical importance as it develops multiplicative thinking among children. The paper also dealt with understanding ways of connecting children's informal knowledge with symbolic representations, for example, the fraction symbol interpreted for division operation. The paper thus made connections between research on fractions and algebra. Subramaniam proposed three broad themes for yielding possible learning trajectories – *children's thinking, cultural support for learning,* and *acquiring symbolic facility*. According to him children's intuitive thinking can be captured by strategies, and action schemes, while sources and support from learning in culture diversity of contexts can identify the learning trajectories, thus making a strong relation between out-of-school mathematics and school mathematics.

Nora Newcombe's paper presents an overview of issues involved in characterizing the course of spatial development. She discusses the important role of education in spatial intelligence and suggests that mental spatial ability is developmental. Newcombe focuses on studies of individual differences and notes that spatial abilities are malleable. In the early years common abilities that are linked with motor development, facilitate performances in both the tasks of mental rotation and perspective taking. Thus there is a strong link between action and cognition that facilitates spatial abilities. Newcombe's work has implications for introducing spatial thinking in preschool education, in media, during play and other active experiences. She further argues that the introduction of such activities will help to reduce differences in spatial abilities by gender and socio-economic status. This talk was based on an article by Nora S. Newcombe and Andrea Frick, and was originally published in the Journal, *Mind Brain and Education,* titled Early Education for Spatial Intelligence: Why,

What, and How, Volume 4, Issue 3, September 2010, Pages: 102–111. The material is reproduced in this volume with permission of John Wiley and Sons, Inc.

Strand 3: Curriculum and Pedagogical Studies

Strand 3 encompassed themes that dealt with curriculum and pedagogical studies of education, such as assessment and evaluation, role of ICT in teaching-learning, classroom interaction and discourse, affective aspects of learning, professional development of teachers and educational initiatives and innovations. Strand 3 included the review speakers: *David Barlex*, *Poonam Batra* and *Pratibha Jolly.* The keynote address by *Shashikumar Chitre* also can be placed in Strand 3.

David Barlex, discussed creativity in the context of design and technology education. He emphasised that creativity has four features: using imagination, pursuing purposes, being original and being of value. Whereas, science requires creativity to reveal and explain, design and technology utilizes creativity in designing and making items to bring them into existence. The five key areas of design decision: conceptual (overall purpose of the design, the sort of product that it will be), technical (how the design will work), aesthetic (what the design will look like), constructional (how the design will be put together) and marketing (who the design is for, where it will be used and how it will be sold) and their interdependence are discussed through a framework. The role of teacher is discussed as facilitating the pupils' designing and making of the product. Further, Barlex describes the journey of designing and making by pupils from the age of 5 to teenagers.

Poonam Batra has reviewed the arena of teacher education and pedagogy in India from the perspective of transforming classroom practices. The paper addresses the issues of existing dualities and conceptual disconnects around child, teacher, pedagogy and curriculum. The paper discusses the academic perspective which emphasizes a radical change in teacher development as agents of social transformations. It explores social interactions within teacher education institutions and how these shape pedagogy. Batra stresses the need to view educational practice not only from the perspective of the knowledge domain that is being taught, but also from the viewpoint of social science and philosophical perspectives. According to her, curriculum changes alone cannot have a great impact if cultural, social and the political expectations are not challenged and alternatives envisioned.

Pratibha Jolly presents a broad overview of physics education research on students' learning, students' conceptions, their learning difficulties, ways of organizing knowledge, understanding of mathematical formulations, problem solving skills and procedural and conceptual knowledge in laboratory. Jolly states that the significant objective of good science education is effective meaningful communication between teacher and student, which requires a bidirectional exchange between them. Another major objective that she mentions is setting criteria to evaluate successful learning of students reflected through qualitative understanding, problem-solving and science process skills. There has been an immense impetus to curricular and pedagogic reform driven by research findings on the Physics Education Research Groups (PERG). The paper gives an overview of the important directions along which physics education research is progressing, as also examples of innovative teaching strategies and curriculum. These are – enhancing learning through active mental engagement; social interactions; research based instructions; enhancing lectures with

research-based strategies; peer instruction; interactive lecture demonstrations; just in time teaching; active learning problem sheets; interactive tutorials; activity based physics tutorials; co-operative problem solving; etc. The paper portrays comprehensive unified learning environments as an answer to the technologically advanced future, where education has widened its access to all. Learning workshop or a studio is considered to be creating an integrated learning experience in physics education research.

Shashikumar Chitre, in his keynote address, spoke about the state of post high school education in India, and proposed a framework for strengthening the same. Chitre mentioned that in India, Indian Institute of Technology (IIT's) have been an ideal example of successfully implemented programmes that have resulted in producing engineers, however he lamented that India still needs similar programmes for basic sciences. A possible model for achieving this could be linking the undergraduate science program with post graduation at university level. As India aspires to become a knowledge power this can only be realized if its school and post high school education system is strengthened and provided with ample opportunities by way of all-round education in science, technology and humanities. Certain issues such as: compartmentalized teaching and learning of a few sub-disciplines and lack of multi-disciplinarity of course structure; inadequate laboratory facilities in schools and colleges; lack of exposure to research methodologies and limited mobility between science and technology, are cause of concern in the system. According to Chitre, the Government of India has conceived of three institutions to fulfill the model mentioned above, namely; *Centre for Excellence in Basic Sciences (CBS)* to provide a liberal well-rounded education; *Indian Institutes of Science Education and Research (IISER)* and *National Institute of Science Education and Research (NISER)*. While being embedded in the university structure, CBS allows undergraduate education to be part of a post-graduate research environment with the emphasis on the experimental component within a multi-disciplinary approach to undergraduate education.

All the talks were followed by question and answer sessions or discussions between the speakers and the audience. The edited version of these discussions are appended in the review volume at the end of each paper. We would like to express our thanks to the authors of this volume who have made a fundamental contribution to the epiSTEME 4 conference. Our sincere thanks also goes to the reviewers for reviewing the papers. We wish to acknowledge the participants of the epiSTEME conference in accomplishing academic deliberations. Acknowledgements are also due to the research scholars at HBCSE for transcribing the discussion sessions. We also thank our colleagues at the Homi Bhabha Centre for Science Education for organizing a successful conference. We especially would like to express our thanks to Manoj Nair for designing the cover page, and to Devashree Prabhu, Adithi Muralidhar, Ankita Patel, Jitender Saini and Damayanti Karade for providing support on the manuscripts.

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