Research and Innovation in Physics Education: Transforming Classroom Teaching and Student Learning

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There is an increasing global understanding of the strategic importance of science in general, and physics in particular, as an instrument for sustainable social progress, economic growth and national development. Indeed, Physics continues to underpin the technology revolution and remains vital to addressing societal aspirations as well as critical environmental challenges facing communities today. Yet, in all countries, there are growing concerns about dwindling interest in physics among young students, lack of inclusiveness and flight of talent to other disciplines. The phenomena emanates from the general perception that physics is difficult to comprehend, and difficult to teach, at all levels. By and large, classroom teaching does not provide a better understanding of the physical world we live in; it does not connect to the real world problems. Then there is felt need to revitalize physics education, tuning it in ways culturally relevant for diverse student population and needs of the communities. Training and capacity building of physics educators is seen to be the critical first step if young students are to be motivated to pursue careers in physics and contribute to development as envisioned by their national goals and build a better world. This entails rigorous action research and most importantly, adopting and adapting best practices.

Research in science education and seminal advances in cognitive science have ushered a major change in the approach to development of teaching programs and instructional strategies. It is now recognized that student's image of science and scientists, beliefs about learning, and cognitive expectations play an important role in her progression. Studies on student construction of meaning and difficulties with fundamental concepts in a comprehensive range of topics in introductory as well as advanced physics have shown conclusively the difference between meaningful learning and passing examinations. The dismal performance of top ranking students on carefully constructed concept indicator tests, even in premier institutions, has raised questions on the efficacy of teaching programs which were hitherto considered as quite innovative and successful.

An important question to ask is what physics we should teach and how we should teach it. Growth of the discipline and its state-of-art, increasingly fuzzy boundaries between disciplines, the ubiquitous technologies in everyday life, the demands of the fast changing workplace, the enticing challenge of solving real world problems for the young: all these mandate crucial changes in the content, context and instruments of physics education. Essential competencies require early exposure to professional tools, an ability to learn with peers and to work in large collaborative teams and social networks.

The presentation will provide a broad overview of physics education research on students learning and implications for teaching-learning of physics. It will delineate the sweeping range of investigations. Through select examples, it will substantiate the research methodology and a theoretical perspective in which to view data on the initial state of students' conceptions and learning difficulties; ways of organizing and using knowledge; understanding of mathematical formulations; problem solving skills; procedural and conceptual knowledge in laboratory tasks. Insight gained from such cognitive studies suggests that to engender conceptual change, the student must be made an active participant in construction of her own knowledge. A few path breaking examples of research-based praxis will illustrate the paradigmatic shift towards learning environments that impel active mental engagement and integrate the use of a variety of resources, including ICT tools, to create learning experiences that are both, hands-on and minds-on.

A major concern is that despite the growing body of knowledge on students learning and recognition of the efficacy of active learning methods, the teaching of physics remains largely traditional in many countries. With few exceptions, this scenario persists in India where physics education continues to operate within the dyadic framework of traditional lecture and laboratory that places few cognitive demands on the student. Altering educational systems with firmly entrenched practices and ushering curriculum reform is a complex task. Alternatives need structural changes, new resource materials, teaching strategies, instruments for assessment, mechanism for dissemination, training programs and pilot trials. For change to take root, local adaptations and indigenous research and development programs are of prime importance.

Within this framework, the few trailblazing efforts being made in India are of great interest. Select examples will be presented from across the country, outlining the thrust of work as well as the challenges in establishing a vibrant physics education research and educational outreach programs. I will describe a triadic model for curriculum reform wherein transfer of pedagogic innovations into the formal classroom is facilitated by professional development programs that aim to provide experiential learning of research-based innovative teaching practices; catalyze the process of reflection through classroom research; and establish a collaborative network of teachers empowered to usher radical transformation. Each step brings its characteristic challenges and demands development of unique instruments and process skills.

On a broader canvas, I will relate international initiatives and action plans led by the International Commission on Physics Education for resource generation and capacity building. These have culminated in the launch of the PHYSWARE "Educate the Educator" series of workshops for disseminating and strengthening active learning and hands – on physics education using low cost equipment and appropriate technologies at the undergraduate level throughout the developing world, with support for regional leaders. The success of the pilot workshop has led to envisioning a community of practice, a critical number of regional leaders and educators who can affect change in the system and bring innovation to mainstream.