Homi Bhabha Centre for Science Education

Self-Review and Vision




Preparatory Document for an External Review

Contributions from all faculty members

Editors: Chitra Natarajan and Jayashree Ramadas

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Last edited

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Authorship and Acknowledgement

This self-review and vision document has been produced in the context of the external review of HBCSE scheduled for October 2014. This document is based on contributions from all of HBCSE's faculty. We hope it will be a live and dynamic document that will enable us to reflect on our work and our achievements and to continually shape our vision of the future of HBCSE.

The zeroth draft of this document was produced by an editing committee consisting of Chitra Natarajan, Savita Ladage, G. Nagarjuna, Jyotsna Vijapurkar and Anwesh Mazumdar, and tabled before the HBCSE Committee at its meeting on September 6, 2013. After the feedback, a second group comprising of Jayashree Ramadas, Chitra Natarajan, Sugra Chunawala and K. Subramaniam wrote the next draft and presented it to the HBCSE Management Board (HMB) and the HBCSE faculty at a joint meeting held on October 17, 2013 at the HBCSE campus. An updated version was uploaded on the HBCSE website on July 16, 2014 for the faculty's comments and contributions. Further, during 2013-14 a separate review of the Science Education graduate school was conducted by K. Subramaniam and Sanjay Chandrasekharan which fed into this document. The next draft was uploaded in August 2014 for comments also from scientific staff and students. We thank all the contributors to this document. All the opinions expressed in this document may not be shared by all faculty. The responsibility for the present version lies with us; in particular the views expressed in Chapter 8 are ours.

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October 1, 2014

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Chapter 1

Overview

Quality science and mathematics education at the school and college levels is vital to the development of the country, and to the growth of science. It is a means to developing the potential of every learner and building strong foundations for a democratic society. In 1972 some scientists at the Tata Institute of Fundamental Research (TIFR) initiated a programme for introducing inquiry-based science in schools of the Bombay Municipal Corporation. In 1974 the Homi Bhabha Centre for Science Education (HBCSE) was initiated as a project in TIFR, under grants-in-aid from the Sir Dorabjee Tata Trust. In 1981 HBCSE became a unit of TIFR and since 1997 it has been a National Centre of TIFR under its School of Natural Sciences. Since 1992 HBCSE has been located at an independent campus near Anushaktinagar, Mumbai.

1.1 Broad goals and synergies

The broad goals of the Centre are, to promote quality and equity in science and mathematics education from primary school to introductory college levels, to support outstanding young people in achieving excellence in science and mathematics and to encourage the growth of scientific literacy in the country. Through its work HBCSE seeks to bring about a change: to influence students, teachers and policy, and to build expertise, resources and opinion that are conducive to good science and mathematics education at all levels.

HBCSE was founded by practising scientists who saw science as a way of learning about the world, finding parallels between the doing and learning of science. Thus questioning, experimentation, reasoning and problem solving have remained integral to all of HBCSE's initiatives, from activity-based school science and education of disadvantaged, under-performing students, to olympiads and undergraduate research programs. In this vein, science education too is seen as a subject of inquiry, in which we explore, develop and evaluate ideas for improving the learning of science, and seek to understand how the larger context of education and society impacts science education.

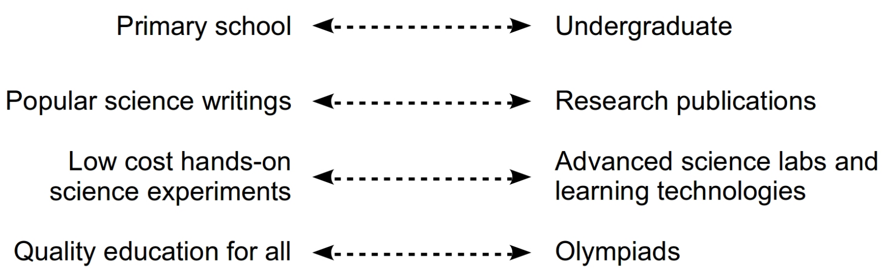

Figure 1.1: HBCSE's work straddles different levels.

HBCSE is a unique institution in several respects. It seeks to bring about a synergy between grassroots work, research and scholarship. It seeks to integrate the pedagogy of science and mathematics with its content. As seen in Figure 1.1, HBCSE's work straddles different dimensions and levels: from education of socio-economically disadvantaged students to training of high-performing students for international Olympiads; from development of innovative low-cost laboratory for schools to setting up sophisticated experiments for college-level physics, chemistry and biology; from writing popular science articles and books to publishing research papers in international journals. These multiple and diverse foci may be viewed together as in Figure 1.2, which shows us striving for a synergy between generating new ideas through research and innovation, translating them into practicable and usable forms (development of materials and methods) and outreach and advocacy to help implement these ideas on a small or large scale.

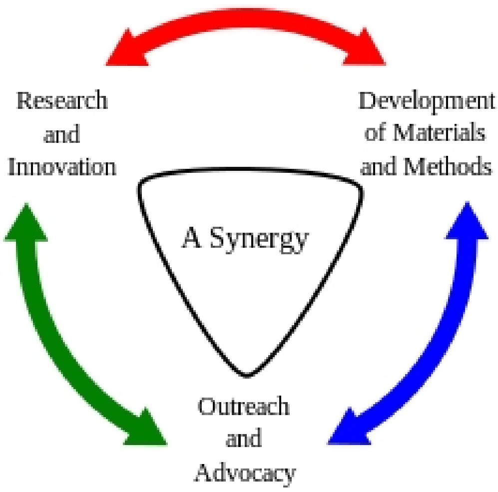

Figure 1.2: A synergy of research, development and action

1.2 Growth of programmes

In the four decades of its existence, HBCSE has evolved in several ways. The Centre has relocated from a few rooms in a municipal school in Nana Chowk to a campus of its own with expansion in infrastructure. The number and variety of programmes taken up have increased. HBCSE's annual financial outlay has increased over the years, and so has the staff strength and its composition as well as the Centre's productivity measured in various ways.

The landmarks in HBCSE's four decades of growth can be captured in terms of three periods: From inception in 1974 to relocation to the campus at Anushaktinagar in 1992, followed by a period up to 2001 of increase in the number of research and scientific staff in the 1990's, and the launch of the Olympiad program at the end of that decade. The Olympiad laboratory block was built during this period. The third period started in 2001 with the formation of TIFR Deemed University, followed by a spurt in research in science and mathematics education as part of the university's faculty for Science Education and birth of the science education graduate school. The NIUS program was launched in 2004 leading to the creation of the NIUS laboratory and guest house facility in 2009. During its growth the Centre established focussed cells in the form of laboratories to carry out research, innovation, development, advocacy and outreach in different domains. Some of these laboratories are, the Integrated Laboratory (1992), Cognitive Laboratory (1992), Advanced / Olympiad Laboratories in Physics, Chemistry and Biology (1996), Mathematics Laboratory (1998), Gnowledge Laboratory (2001), Hindi Cell (2004), Design and Technology Laboratory (2005), and NIUS Laboratories in Physics, Chemistry and Biology (2004) and Astronomy (2011).

1.3 Growth in financial outlay

In 1974-75, HBCSE had a meagre budget of rupees 0.8 lakhs which was based on grants received from Sir Dorabji Tata Trust and NCERT. In a span of ten years, that is by 1985, this budget had increased to only around rupees 7 lakhs and came mainly from non-plan funds. In 1992, HBCSE's budget was around 32 lakhs. In 1993-94, HBCSE had planned projects and received an annual plan fund of around 57 lakhs, substantially increasing its annual funding to around 86 lakhs. Since then, HBCSE's planned activities and consequently the funding for these have been increasing. The spurts in funds indicated in Figure 1.3 correspond to the major international olympiad events that were organized by HBCSE, such as the International Chemistry Olympiad (IChO, 2001-02), when the budget doubled from around 200 to 400 lakhs and the International Astronomy Olympiad (IAO, 2006-07), when the budget doubled from 530 lakhs to 1,115 lakhs. The Ninth Plan (1998-2002) requested funding for initiation of Physics, Chemistry, Biology and Astronomy Olympiads, and conducting of IChO. In the Tenth Plan (2002-07) period, IAO and IBO were hosted by HBCSE. In the Eleventh Five Year Plan (2007-12) HBCSE hosted the Asian Science Camp, and coordinated the funding for the Asian Physics Olympiad. In the Twelfth Plan period the major Olympiads hosted are the International Junior Science Olympiad (2013), and the International Physics Olympiad, to be conducted in July, 2015.

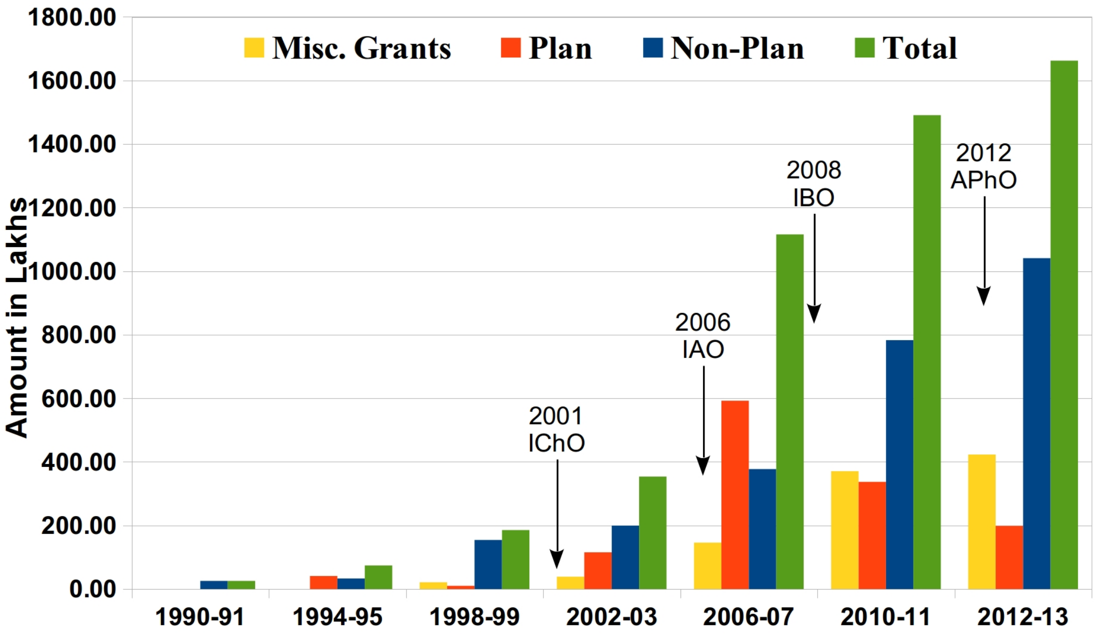

Figure 1.3: HBCSE Annual expenditure (1985-2013)

1.4 Growth in human resources

The permanent staff strength at HBCSE has been limited over the years (Figure 1.4). In 1974 at its inception HBCSE had a staff of 9 members of whom only 2 were academic. From 1976 to 1993 the staff strength slowly rose from 14 to 27, of whom 8 were academic members. After 1992, following the move from Nana Chowk to the new HBCSE location near Anushaktinagar, HBCSE staff grew to 40 in 1994. This growth was largely due to an increase in the administrative personnel from 6 in 1993 to 14 in 1994. From its inception in 1974 till 1995, there was no technical section. The shift to the new campus and associated maintenance requirements brought in the category of technical staff. The next spurt in the staff strength was in the year 2005, which followed the creation of the NIUS programme at HBCSE in 2004, when the academic members grew from 13 to 19 and scientific staff grew from 10 to 17. The current faculty strength is 18, and the scientific staff are 18 in number.

1.5 Creating an impact

HBCSE's early approach had been to focus on groups of schools, particularly those serving disadvantaged sections of students, carry out in-service teacher orientation and look for impact on teaching practice over a period of 2-3 years. In this process the cognitive, linguistic and socio-cultural factors hampering education were sought to be identified and remedial methods were to be developed and tested. This approach was later felt to be limited, in terms of actual long-term impact on the schools, in the

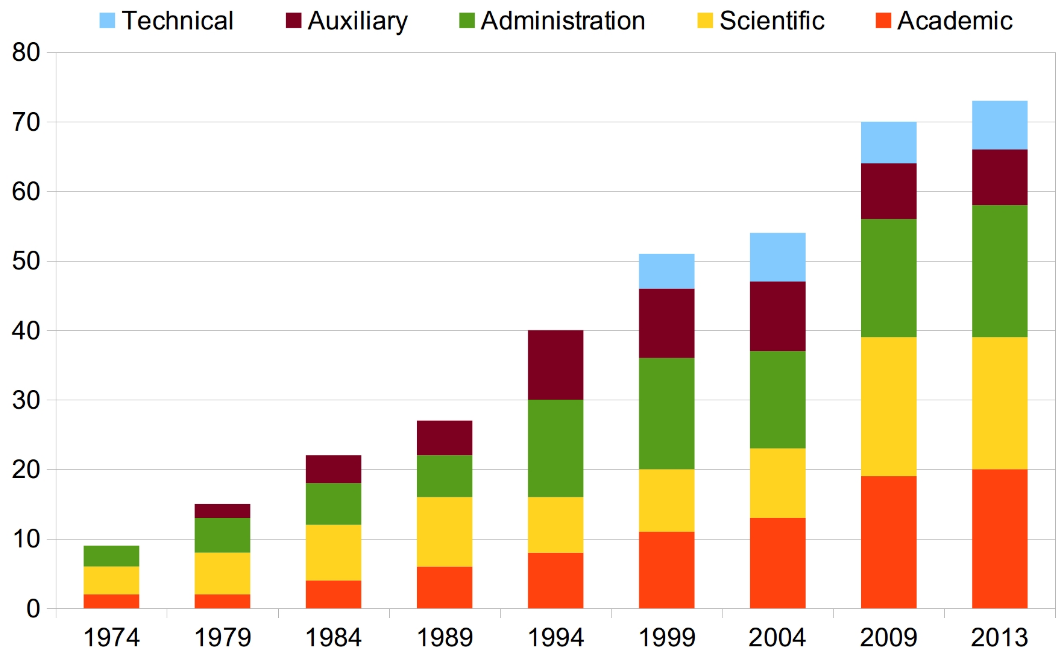

Figure 1.4: Growth of staff strength

facility it provided for sustained trialling and perfecting of materials, and in attaining the rigour and quality required for internationally peer reviewed research. However the strength of the field work approach lay in the opportunities for continual teaching practice and the rich experiences from the field gained by HBCSE members, who later contributed to research and developmental work in different ways. This contact with practice is essential for sustaining meaningful R&D, which could lead to creation of a significant body of materials and methods, and go on to perceptibly impact the education system.

It may be justifiably claimed that, despite the small staff strength and relatively low budget of the Centre, HBCSE has already had some impact on the educational scenario in the country. Today HBCSE is recognised as the premier institution in the country devoted to research and development in science and mathematics education and popularisation. It has been India's nodal centre for Science and Mathematics Olympiads for over a decade and half. The Centre is well-regarded at the national and state levels and continues to be approached by several state and national level institutions, including the policy-making bodies of the country, with requests to contribute in major ways. Most staff members at HBCSE are simultaneously involved in multiple essential and significant projects in one or more areas of research, development and outreach. HBCSE has initiated in 2004 a biennial series of international conferences, epiSTEME, that has served to highlight theoretically informed practice-based educational research in the country. It has helped develop and maintain links with the international research community, which have benefited other institutions and educators outside of HBCSE. Now we need to be more ambitious in striving for an international impact of our research and development, and a national impact on the practice of science education in the country.

The achievements so far have been possible because HBCSE has been fortunate to attract highly motivated and imaginative staff members with a passion for science and mathematics education, who were given the freedom, facilities and guidance to pursue their field of interest. Forty years on HBCSE is looking for the induction of a new generation of faculty members, scientific staff and students who are passionate about and competent to pursue a career in science and mathematics education. We are looking for focused collaborations with appropriate institutions and individuals. Most important of all we are seeking to renew our mandate, to discover within us a shared sense of institutional purpose. With these elements in place we will be well placed to aim for a significant impact nationally and internationally.

1.6 Review questions and way ahead

1. Have we been able to achieve the integration that we have striven for, between the multiple and diverse foci of Figure 1.1? Do we experience any tensions between these foci?

2. Have we been able to achieve the synergy that we have striven for, between research, development and outreach, as shown in Figure 1.2? What are some of our successes, failures and challenges in this regard?

3. To what extent are such integrations as above desirable and feasible? What are some ways of achieving the synergies described in Section 1.1?

4. Do we believe, as claimed in Section 1.5, that teaching practice and field experiences are essential for sustaining meaningful R&D that could lead to national and international impact? Do we have enough opportunities for teaching or are we limited by the organisational load of our programs?

5. In what ways have we impacted, in however modest a way, science education and science education research nationally and internationally?

6. Section 1.2 describes three periods of growth till date. How do we envisage the next, forthcoming period of our growth?

7. We now have in-principle sanction to grow from the current faculty strength of 18 (Section1.4) up to a maximum of 25 faculty members. What should be the profile of the new faculty and how should we go about in our search for them? Is our current advertisement process adequate?

8. As the next few chapters show, our variety and range of activities is broad. Reviewers at individual peer reviews often ask for our criteria, or yardsticks of assessment of faculty members at different levels. These need to be derived from the kind of things that we do, which are given in Appendix G. The review process should help evolve the criteria.

9. Questions and comments from Prof. N. Mukunda, member, HBCSE Management Board, are in Appendix K.

Chapter 2

Research in Science, Mathematics and Technology Education

2.1 Research in the early years (1976-96)

Research at HBCSE originated in the context of its early field work and curriculum development programs which were carried out exclusively with the government school system and thus focused on students from socio-economically deprived backgrounds. In 1975, HBCSE conducted the first fully computerized State-wide survey of all secondary schools in Maharashtra in collaboration with the State Institute of Education, Pune, covering about 5000 schools and 18000 teachers of science and mathematics (Kulkarni, Ramani, & Taskar, 1978). The titles of papers in Appendix A indicate the nature of research interests envisaged in the founding years. Research on classroom interaction and in-service teacher education went on to formed part of HBCSE's field projects in rural areas in the late 1970s and '80s. Other research topics included language and science, knowledge frameworks of children and their alternative conceptions in topics of physics, chemistry and biology, learning hurdles in school mathematics, career aspirations of underprivileged students and mathematical modelling of educational processes.

Language simplification of science textbooks was found to lead to better student performance and enhanced interaction in the classroom (1980-83) (Kulkarni & Gambhir, 1981; Kulkarni, 1988). Development of a minimum science curriculum for implementation with a literacy program led to detailed appraisal of facets of the non-formal system of education (1983-86) (Kulkarni, Ramadas, Ozarkar, Bondale, & Gambhir, 1991). A program of remedial education for socio-economically disadvantaged students based on active learning, language development and boosting self image of students resulted in improved scholastic achievement at the secondary school level (1980-86) (Kulkarni, 1980; Agarkar, 2010). This work led to several projects of teacher development aimed at improving academic performance of first generation learners (1985-99) (Table 4.1).

During this period studies were conducted on classroom interactions (Ramadas & Kulkarni, 1982), collaborative learning, inclusive education, diversity in science education, students' and teachers' attitudes to science and mathematics, and out-of-school learning. Some of the early studies have aimed at uncovering the career aspirations of socio-economically backward students and girls (1985-1992) (Chunawala, 1989, 1991), exploring attitudes of students to mathematics and to other subjects (1992-95) (Chunawala & Pradhan, 1993), studying urban and tribal students' alternative conceptions about living and non-living, their ideas on plants and forests and experiments (1996) (Chunawala, Natarajan, Apte, & Ramadas, 1996; Natarajan, Chunawala, Apte, & Ramadas, 1996; Ramadas, Chunawala, Natarajan, & Apte, 1996).

2.2 Discontinuation, and a fresh start (2002-present)

There was a period during 1996-2001 when, as a matter of policy, most research activity at HBCSE was discontinued and the focus shifted to material development and Olympiads. After the creation of the HBCSE faculty in 1999 and the subsequent formation of the TIFR Deemed University in 2002 with Science Education offered as a Ph.D. subject, research projects were initiated afresh and the graduate school program was put on a sound footing. Since 2004, the epiSTEME series of conferences have served to develop and maintain links with the international research community and nationally, to initiate theoretically informed, practice-based educational research.

The Centre's research in Science, Technology and Mathematics Education (STME) is now informed by current perspectives in cognitive science, developmental psychology, history and philosophy of science and socio-cultural aspects of science and education. Pre-Ph.D. programs in these areas as well as in research methodology serve to orient incoming students into STME research. Between 15 and 20 Research Scholars pursue Ph.D. in Science Education as part of the TIFR Deemed University.

2.3 Science education

2.3.1 Cognitive studies of science learning

(Contributing faculty: Jayashree Ramadas, G. Nagarjuna, Savita Ladage, Sanjay Chandrasekharan; Past members: Arvind Kumar, Bakhtaver Mahajan)

Cognitive issues occur naturally in the course of doing innovative work in science education, in designing better ways to convey science to children and adults. Inevitably such work comes up against questions of cognitive origin - How do we learn? Why do we learn certain things easily and not others? What kinds of knowledge and modes of thinking are useful for students to learn and teachers to better teach science and mathematics?

A modest scaled activity of cognitive research in the area of science learning has been carried out at HBCSE since the 1980s. This work arose in the context of curriculum development and teacher education, and it investigated students' understanding of several content areas of physics, chemistry, and biology. The studies included students' spontaneous conceptions in light, heat, matter, motion, life, human body, health and evolution; students' mathematical understanding in several areas; concept mapping (Section 2.3.6); model-based reasoning including visuospatial and embodied modes of reasoning (Section 2.3.3) as well as situated and distributed cognitive models (Section 2.3.4). In many of these these studies concept areas were identified in which learning barriers and alternative conceptions were observed and cognitive and affective aspects studied. Studies on students' ideas about evolution were informed significantly by the history and philosophy of science (Bardapurkar, 2005). Other studies on students' ideas about evolution have led to the development of new teaching methods (Haydock, 2014, In press-b). Some of the better-cited research at HBCSE has been, in the 1990s, a set of three studies on alternative conceptions in Galilean relativity (Section 2.3.2) and a study of students' understanding of health (Section 2.5). In the 2000s, three papers in a special issue on visual and spatial modes in science learning (Section 2.3.3) were well cited. A recent area of research, which uses theoretical frameworks and experimental methodologies drawn from mainstream cognitive science, is 'Learning and Reasoning with Representations' (2.3.4).

2.3.2 Physics education research (PER)

(Faculty: Jayashree Ramadas, Vijay Singh, Rajesh Khaparde; 2 scientific staff[1], 3 Ph.D.s.; Past members: Arvind Kumar, H. C. Pradhan)

Physics education research (PER) has come a long way from being guided by common sense insights and intuition to systematic investigation of student learning in depth and detail. Some of of the initial areas of PER at HBCSE concerned studies of students' conceptions in physics, and were guided by the constructivist view of learning, especially Piaget's personal construction of knowledge. A comprehensive study of alternative conceptions among introductory Physics students in different aspects of Galilean relativity was carried out by the group in the 1990's (Panse, Ramadas, & Kumar, 1994; Ramadas, Barve, & Kumar, 1996a, 1996b). The fascinating parallels between some of students' ideas and ideas that arose in the history of physics were also noted. A more recent study probed what students understand by the principle of relativity in the context of Newtonian mechanics (Bandyopadhyay, 2009). There was also studies on students' ideas on concepts relating to elementary kinetic theory (Pathare & Pradhan, 2005, 2010).

A series of studies were conducted on the core ideas in general relativity (Bandyopadhyay & Kumar, 2010b, 2010a, 2010c). Using an innovative investigation tool, these studies probed the nuances of students' understanding as they engaged with the subject at the beginning of, during and after instruction.

An offshoot of the Olympiad and NIUS (see Section 6.1.6) work has been work on concept inventories. In a first of its kind effort Pathak and Singh carried out a survey in

[1] Working with the Olympiad and NIUS programs

vernacular languages of over one thousand students in the Hindi and Gujarati speaking belt to ascertain student misconceptions on friction in rolling bodies (Singh & Pathak, 2007). In further and more systematic studies Mashood and Singh (2012) constructed a concept inventory on rotational kinematics.

Laboratory development has been a unique aspect of HBCSE's approach to science education from primary school to undergraduate levels. A significant area of research has been the relation between demonstrations, experimental problems, and integration of procedural with conceptual understanding. *Experimental problem solving*, a novel instructional strategy was designed to to encourage student's independent thinking and planning, and hence foster the development of procedural understanding. Also an assessment strategy to evaluate various abilities related to experimental physics was designed. The strategy was based on four tools of assessment, namely, test on conceptual understanding, test on procedural understanding, an experimental test, and the continuous assessment. A workshop module for teachers on *Procedural Understanding in Physics* was designed and the acceptability and feasibility of activities based on procedural understanding were studied. A large number of demonstrations and experimental problems in physics were developed with suitable instructional strategies, and tested for their efficacy in laboratory training of undergraduate students (Khaparde & Pradhan, 2002, 2009; Khaparde, 2010; Jetty, Suman, & Khaparde, 2012; Khaparde, 2014b, 2014a).

2.3.3 Visuospatial reasoning (VSR)

(Faculty: Jayashree Ramadas, K. Subramaniam, Aniket Sule; 2 Ph.D.s)

Science learning in the early years is (or ought to be) largely experiential in nature. In fact, field experience and experimentations are integral to the process of science. On the part of the scientist, and the learner, these experiences are mediated through the human sensory and perceptual systems. A fundamental problem in science learning is, "How do inductive generalisations and model-building arise from first hand experience?" Here the close linkages between perceptual, motor and cognitive activity need to be investigated in the context of science learning. Diagrams are an example of *epistemic actions* that connect a lab or a field situation with the representations and concepts of science. Other examples of such actions are manipulation of concrete models, use of gestures and also mental simulations.

Early research at HBCSE during the 1980s and '90s included empirical studies on students' drawings and schematic diagrams (Ramadas, 1982; Ramadas & Driver, 1989; Ramadas, 1990; Ramadas & Shayer, 1993). Work after 2005 explored topics which posed visual and spatial challenges for students, like, human physiology (Mathai & Ramadas, 2009), astronomy (Subramaniam & Padalkar, 2009), water cycle (Vinisha & Ramadas, 2013) and DNA structure (Srivastava & Ramadas, 2013). Some theoretical contributions emerging from this empirical work have been, first, a notion of *transformational reasoning*, referring to an imagined manipulation of a structure or a system (for example, the digestive system), or an imagined change of viewpoint of an observer which, we suggest, enables mental visualisation in science (Mathai & Ramadas, 2009).

Second, a new framework has been proposed for the design of gestures which serve to connect phenomena as well as their external representations, like models and diagrams, with internal mental models that people use to reason in science. A study of physics graduates' and architecture students' reasoning about phases of the moon (Subramaniam & Padalkar, 2009) led to a conjecture that was refined through a classroom design study for Class 8 students. The pedagogical insight was that gestures of cognitive significance can be designed to link concrete models with abstract diagrams, leading to learning of concepts in science. Specific gestures and actions facilitated communication between teacher and students, and also influenced spontaneous individual and collaborative problem solving (Padalkar & Ramadas, 2011). Some of this research was showcased through three of the eight papers included in a Special Issue of the International Journal of Science Education (Ramadas, 2009) on *Visual and Spatial Modes in Science Learning*. Two Ph.D. theses were awarded on this work in 2011.

The results on gestures were elaborated in a study of undergraduate students' visualisation of DNA structure and function. The "gesture link" was generalised to the case of several external representations, including skeletal models and diagrams of DNA structure. Analogical thinking and mental simulation involving "character viewpoint actions" were found to work as tools for visualisation. The study was published as an invited chapter in the Springer series *Models and Modelling in Science Education* (Srivastava & Ramadas, 2013).

The above pedagogy for visuospatial reasoning is grounded in the theoretical perspective of embodied cognition, which aims to link perception and action on the one hand, with abstractions of science on the other. In 2014 this work is being extended to a sky map problem in the Indian National Astronomy Olympiad, as part of an overall effort to strengthen science education research at HBCSE by allowing it to encompass the Olympiad and NIUS programs (Section 8.5).

Graphicacy and students' drawings

(Faculty: G. Nagarjuna, Karen Haydock)

The learning possibilities of external representations are neglected in schools. In rare instances when teaching goes beyond verbal methods students are made to merely copy textbook drawings or learn them by rote. Innovative teaching methods have been developed at HBCSE to address graphicacy (Dhakulkar, Nagarjuna, & Dhurde, In press) and learning opportunities in students' drawings (Haydock, In press-a).

2.3.4 Learning and reasoning with representations

(Faculty: Sanjay Chandrasekharan; 2 students to complete)

To understand observed phenomena, science postulates entities and processes that cannot be tracked using human sensory and perceptual systems. Examples include atoms, DNA, orbits, molecular forces, evolution, equilibria, etc. To refer to these imperceptible entities and processes, a range of external representations are used, such as pictures, mathematical equations, chemical structures and symbols, physical models, animations, textual descriptions, graphs, computer simulations and combinations of these media.

Learning of science requires learning to imagine the postulated entities and processes, with the help of the external representations. The research area titled Learning and Reasoning with Representations (LRR) examines how students learn to imagine these postulated entities and processes, using different representational systems particularly how students learn to integrate, transform and reason across different representational systems. The focus is on understanding the limitations of different representations in helping develop this type of imagination, and how these limitations could be addressed. Part of this research involves developing and testing new representations and media systems, such as simulations with equations and graphs that are manipulable, to understand how such interaction possibilities improve students' ability to integrate different external representations.

2.3.5 Curriculum and pedagogy for middle school science

(Faculty: Jyotsna Vijapurkar; 1 Ph.D. student to complete)

Studies of curriculum and classroom transaction in combination with cognitive studies of students' conceptions have contributed to the development of the Homi Bhabha Curriculum for primary and middle school science (for primary science see Section 3.1). An ongoing middle school science curriculum project investigates what to teach in science at the middle school level, and how. Teaching techniques evolved and were refined over the years through the classes conducted for developing curricular material. The main concern was cognitive outcomes, such as, students' cognitive readiness for a concept, and how concepts can be successfully taught in a low cost, easily doable manner. However, a range of outcomes other than conceptual understanding of the science content of the curriculum emerged: higher engagement with science, changes in the way students viewed and learned science and better performance in their school exams to higher levels of confidence and improvement in mathematics and language achievement in their school exams. These outcomes of inquiry teaching were investigated. A comparison group was taught in the traditional manner by teachers specifically hired for the purpose, in order to control for other factors that may affect the outcomes. Analysis of data from the detailed classroom observations that were carried out provided a comparison of what the teacher does in inquiry and traditional classes, thus contributing to the characterisation of inquiry teaching. The outcomes were corroborated through questionnaires and interviews of students, and additionally with questionnaires for parents and interviews of students' peers (Kawalkar & Vijapurkar, 2013). The project also included studies on middle school students' alternative conceptions: students' difficulties with visualising the biological cell as 3-dimensional, and students' ideas of spontaneous generation of life (Vijapurkar, Kawalkar, & Nambiar, 2014).

2.3.6 "Constructionist" learning environments and new media

(Faculty: G. Nagarjuna; 4 Ph.D. students to complete)

Much of the design of curriculum and pedagogical practices in the majority of the schools across the world focused mainly on passive instructional practices (delivery of content and assessment for the purpose of graduation) in alienated classrooms. They served the purpose of supplying graduates for the growing administrative and industrial needs of developing economies. They did not contribute to making creative citizens who participate in investigative activities with rigorous engagement. Economic well-being of any country depends a lot on the quality of what and how the nation *produces* and not merely on what the nation *consumes*. Could learning science and mathematics be situated in close-to-life production (construction) context? Ths led to research inspired by the constructionism and connectionism (that learning happens most effectively and naturally when people are engaged in making tangible objects in a collaborative learning environments), as against instructionism. Considering that much of this research is facilitated by the use of the new media (Information and Communication Technology), HBCSE began experimenting and exploring a new area of research and development.

As a part of the gnowledge lab's engagements the following research and development projects are undertaken:

- Re-representing concept maps as 'Refined concept maps' to help develop meaning and rigour while learning by focusing on variable properties of concepts instead of concepts (Kharatmal & Nagarjuna, 2006, 2008, 2013).
- Designing and implementing an online publishing framework to model structure and dynamics of knowledge (semantic) networks as knowledge cartography (gnowsys-studio) (Nagarjuna, 2009a; Nagarjuna, Kharatmal, & Nair, 2010).
- Investigating the properties and relations between software components to model the emerging knowledge network as a complex system (Nair, Nagarjuna, & Ray, 2014).
- Making toys and recording variable properties of events through digital dataloggers and live graphical visualization facilitated by computers to engage students in experimental and model based reasoning (Dhakulkar et al., In press; Dhakulkar & Nagarjuna, 2011).
- Analyzing the the means and methods of the cognitive shift from qualitative to quantitative descriptions and explanations through model based reasoning in a collaborative undergraduate biology education (CUBE) project (Ghumre, Nagarjuna, & Arunan, 2013).
- Learning Science and Mathematics in a close-to-life production context for learning numeracy and literacy skills (Shaikh, Nagarjuna, & Chandrasekharan, 2013).

2.4 Mathematics education

(Faculty: K. Subramaniam; 2 scientific staff[2]; 1 Ph.D., 4 students to complete; Former members: H. C. Pradhan and late Arun Mavalankar)

School education in India has expanded rapidly to provide comprehensive access to a vast and growing population. Mathematics is a core subject through all school years and beyond, and is a core component of all large-scale assessment of educational outcomes. Large-scale assessments of school learning have indicated that, across the country, learning outcomes in general and in mathematics especially, are extremely low. While addressing this issue requires a systemic effort to make the school system more functional, the work of the mathematics education group at HBCSE is aimed at identifying critical factors that need to be strengthened to improve the learning of mathematics in schools, and to develop capacity and resources that can contribute to bringing about this change. The work consists of research, development of materials and outreach activities which include influencing policy. In this section, we focus on the research dimension.

2.4.1 Brief history

The involvement of the TIFR main institute in mathematics education dates back to two major international conferences on mathematics education which were organized under the auspices of the International Commission on Mathematics Instruction in 1956 and 1960. The proceedings of these conferences show the participation of leaders in the field of mathematics education of the period. It is a remarkable (and regrettable) oversight that historically there was no continuity between these conferences and the launch of HBCSE, and its mathematics education programmes. At HBCSE, mathematics education was a part of its early programmes with SC/ST students of BMC schools in the 1980s. As a stream of work in its own right, it gathered momentum after the two Indo-US workshops on mathematics education in 1989 and 1992, which exposed HBCSE members to current research and developments in mathematics education research in the West. With the establishment of the graduate school of the TIFR Deemed University in 2001, focused research in mathematics education was initiated under the strands described in this section.

2.4.2 Research areas (mathematics education)

The research foci of the mathematics education group at HBCSE has been driven by the needs identified through its work on curriculum development and in-service teacher professional development. One of the main areas of research has been evolving learning strands for core topics in middle school mathematics such as algebra, fractions and

[2] One working in development and outreach, one in media support for the Centre

multiplicative reasoning, and measurement. The methodology includes cycles of teaching design experiments which iterate between reorganization of instructional topics and investigating students' responses to variations in approach.

Much prior research on algebra learning has focused on developing aspects of algebraic thinking such as generalisation and understanding variation and functions. Research on how students meaningfully absorb the syntax and structure of symbolic expressions has been limited to exploring inductive approaches using spreadsheets, or structural approaches involving parsing expressions using "tree" representations. We developed a visually-guided, structural approach that identifies the additive components of a symbolic expression (called "terms"), and develops a meaningful understanding of the relation between the value of an expression and its "terms". Participants in the teaching design experiment developed flexible ways of evaluating expressions, identifying equivalent expressions, and obtaining a feel for how transformations of expressions affect the value of the expression. This was done in parallel with both numerical and algebraic expressions, allowing strong connections to be built between the two domains (Banerjee & Subramaniam, 2012).

Exploring the history of the development of algebra in India revealed that leading Indian mathematicians viewed algebra as the foundation for arithmetic, rather than as a generalisation of arithmetic. This illuminated the perspective adopted in the "terms" approach to algebra teaching described above as supporting thinking about the quantities underlying symbolic expressions, and the notion of "operational composition" of expressions (Subramaniam & Banerjee, 2011). Recent historical work on the Indian mathematical tradition of combinatorial problems indicates that unique representations of natural numbers using not only powers of ten (as in the decimal system), but also powers of two (binary system), Fibonacci numbers and other kinds of numbers, were recognized. Such unique representations were used in solving several combinatorial problems, which has implications for the pedagogy of the arithmetic-algebra relation that remain to be explored (Sridharan & Subramaniam, In press).

We developed an approach to teaching fractions for the primary and middle school, which aims to explicitly integrate different interpretations of fractions (part-whole, ratio, quotient, measure, operator), anchoring these in contexts of equal sharing (Banerjee, Subramaniam, & Naik, 2008). The relation between fraction understanding and multiplicative reasoning (Subramaniam, 2013), was explored in several cycles of teaching design experiments. However this research has been inadequately reported.

Another study has explored the nature and extent of mathematical knowledge, especially related to measurement, that middle-grade students from urban, low SES backgrounds gain from work-contexts and its implications for school learning of mathematics (Bose & Kantha, 2014). The participants in the study are exposed to work-contexts from an early age and access the funds of knowledge in the community. A teaching intervention explored the features of mathematical instruction that makes strong connections with out-of-school knowledge and characterized a set of shifts that lead from informal to formal mathematical learning. (Subramaniam & Bose, 2012; Bose & Subramaniam, 2011, 2013)

A second major research focus is developing models of in-service teacher professional development. The nation invests heavily in in-service teacher development programmes, but this activity is ill-structured, ad-hoc and ineffective. Our research is aimed at clarifying the kinds of support that in-service teachers need to improve their teaching, and to evolve models of working with teachers that leads to deep changes in their beliefs and practice. This research strand draws on the curriculum strands research.

We found that teachers hold strong beliefs about the teaching and learning of mathematics and the nature of mathematics that are not consistent with the vision articulated in the National Curriculum Framework (R. S. Kumar & Subramaniam, 2013). However, in-service teachers engage in discussions of mathematical knowledge relevant for teaching, expressing their agency in articulating and challenging the knowledge and the beliefs that they hold (R. S. Kumar, Subramaniam, & Naik, In press). A research study involving collaborative planning of teaching focused specifically on integers and drawing on prior research in the field, evolved a framework for the meaning of integers that was shared with teachers. The framework identifies three components of meaning – of the minus sign, of integers, and of the integer operations of addition and subtraction. The study indicated that such a framework is a critical part of the specialized content knowledge needed to teach the topic of integers. Moreover, such knowledge is not available to teachers through their own education, or through their teaching experience, which has implications for pre- and in-service teacher education.

2.4.3 Mathematics education research at HBCSE: critical appraisal

The research studies at the Centre have maintained an organic link with the curriculum development and teacher professional development needs of school mathematics education in the country. Research students participate actively in outreach activities along these dimensions and have a sense of relevance in regard to their work. Not only do they get research experience, but also hands-on experience in working with students, teachers and teacher educators. Several of them have begun to participate in important policy-framing or resource-building activities led by institutions outside of HBCSE.

There is also an encouraging convergence in the various strands of research. The research on learning of algebra, fractions and multiplicative reasoning, and measurement are related in interesting ways, some of which remain still to be explored. The study on connecting out-of-school knowledge with school learning has focused on the topic of measurement, which promises to illuminate a critical aspect of the curriculum. The collaborative research study with teachers on the topic of integers has connections with the algebra learning research, and a current study with teachers on the topic of decimal numbers has connections with the research on learning fractions. Much of the research on in-service teacher professional development is located in the context of outreach workshops for teachers, and informs such efforts.

A number of papers have been presented at the two leading international conferences in mathematics education – the ICME and PME conferences, which has helped to create a visibility for the group. Publications in journals have so far been few. The work on algebra education has a reasonable number of citations, finds a mention in a 2006 handbook on mathematics education research, and is a part of a recent compilation of international research on the topic (Subramaniam & Banerjee, 2011). Recognition of the group's work led to the group leader being invited to edit the India section for the First Asian Sourcebook of Research in Mathematics Education, and an invitation to be on the plenary panel on opportunities to learn mathematics at the PME 2012 conference. The research has also been published in relevant Indian fora, creating an awareness and impact among the small community of mathematics education researchers in the country.

The number of journal papers has been exceedingly small given the range of research, and dates only from recent years. Publication in leading international research journals on mathematics education needs to be foregrounded as a priority. Further, the cycle of data collection, analysis and publication needs to be shorter, more intensive and focused. This may call for a fresh appraisal of specific problems to be focused so that future research consolidates the work done so far.

Most of the research in mathematics education at HBCSE has been done by a group consisting of only one faculty member with a group of Ph.D. students and one scientific assistant. Although we have had one post-doctoral fellow with a Ph.D. in mathematics working with the group for a period of three years, she did not have a background in mathematics education research. This has put severe constraints on managing time and focus for the faculty member, and the group as a whole. It has also created several challenges in aligning the strong interests of each individual research student with the overall direction of the mathematics education research programme. Despite this, significant research has been done, due largely to the commitment, talent and energy of the young members that the group is fortunate to have had.

2.4.4 Growing mathematics education research in India

Mathematics education has emerged in several countries as an academic discipline that is grounded in research and scholarship. This academic discipline is yet to emerge in India. Looking beyond HBCSE, the mathematics education group has initiated joint activity with key external organizations. HBCSE played a leading role in conceiving and implementing the National Initiative on Mathematics Education (NIME) in the years 2011-2012. Five regional conferences and a national conference were held under the NIME initiative, which brought together mathematics educators, mathematics education researchers, mathematics teachers and research mathematicians across the country. A status report on mathematics education in India (Subramaniam & Bose, 2012) and a set of video films highlighting the challenges and the major initiatives in the country were published. The status report, based on research, is perhaps the only report giving an overview of different aspects of mathematics education in the country. As part of the NIME initiative about 25 researchers and research students in mathematics education participated and made presentations at the ICME-2012 in South Korea. (ICME is held once every four years.) The initiative has created awareness and a sense of community among those working in mathematics education, has identified research needs and a momentum towards carrying out research, which can be built upon in the future. All the NIME materials are available at http://nime.hbcse.tifr.res.in.

The mathematics education group has also organized several short workshops and seminars in which leading mathematics education researchers from abroad and from India have delivered talks. These include the coordination of satellite workshops for the epiSTEME conferences and the Indo-Swedish collaborative workshops in mathematics education (2009-2011), and a two day discussion seminar (Aug, 2010). Such interventions are important in shaping the emerging community of mathematics education researchers at HBCSE and elsewhere in India.

2.5 Socio-cultural studies in the context of education

(Faculty: Sugra Chunawala, Chitra Natarajan, Savita Ladage; 2 students to complete; Past member: Bakhtaver Mahajan)

Research at HBCSE, since 1980s, was led by a focus on socio-cultural aspects of education, primarily related to first generation learners and those coming from economically and socially disadvantaged backgrounds. The studies have included attitudinal studies of students and teachers towards science and scientists, topics in science and mathematics, other school subjects, design, technology, as well as diversity and inclusion. The Centre is recognised for its work on socio-cultural issues, specifically on gender and education and on the education of the socially and economically disadvantaged, both at the national and international levels. A member was invited to the working group on gender in the development of the National Curriculum Framework 2005 (NCF 2005) (NCERT, 2005). Four of the major studies in this area have been part of international collaborative research.

Students' perceptions on health, a research study (1994-96) set out to gain an understanding of student's ideas with reference to air-borne and gastro-intestinal diseases, in urban and tribal schools in Maharashtra. It gave insights into students' inadequate understanding of the effect of nutrition and genetic factors on health despite these being addressed to some extent in textbooks (Mahajan & Chunawala, 1999).

Gender aspects in science education have been of interest for almost three decades. The insights from the earlier studies were consolidated in a permanent exhibition on Gender and Science at HBCSE in 2003. It also led to a request from Department of Science and Technology to analyse the middle school text books for gender bias in visual and textual representations, which revealed several biases on the part of curriculum and textbook developers. For instance, the books rarely highlighted women's role as knowledge generators (Chunawala, Vinisha, & Patel, 2009).

"Students' ideas about science and scientists" (SAS-1995-98) was an international collaborative research study undertaken among middle school students, and sponsored by NORAD, the Norwegian Agency for Development. Amongst several findings, some interesting ones among Indian students, irrespective of their gender, were (a) the positive image they had about scientists, (b) who were often seen to be males, and (c) their perceptions about physicists as being imaginative and creative, and biologists as caring (Chunawala & Ladage, 1998).

'Multilingualism, Subalternity and the Hegemony of English in India and South Africa" (2001-2004) coordinated from Frankfurt, Germany and University of Cape Town, was an interdisciplinary collaboration in research, teaching and educational practice between persons and institutions in Germany, India and South Africa. The HBCSE research group argued for parallels between language and technology as cultural artefacts, and initiated a study of the potential of design and technology for legitimising multiple modes of expression in Indian classrooms.

"Relevance of Science Education" (ROSE 2003-05) was an international project, conducted in about 40 countries by research organization of the respective countries. The project aimed to gather information about affective dimensions of young learners' relations (15 year-olds) to science and technology, through a questionnaire. The results from the project showed that students in India find school science more interesting than other subjects and that it increases their career chances. The differences in the responses of students from Mumbai revealed that most girls preferred to learn about biology and its allied fields, while boys preferred to learn about chemistry and its allied subjects

"Science Education for Diversity" (SED 2010-2013), funded by the European Union's Seventh Framework Programme, involved a collaboration among research groups from the University of Exeter, UK, the Netherlands, Turkey, Lebanon, India (HBCSE) and Malaysia. In the Indian context this study was based on an intervention in schools aimed at sensitising students and teachers about significance and relevance of diversity in classrooms. Interventions in three schools with students and teachers also indicated that both did not perceive critical reasoning, argumentation and dialogue as an intrinsic part of learning science (Chunawala, Birwatkar, Muralidhar, & Natarajan, 2013). A majority of teachers believed that key barriers to teaching of science were differential academic abilities rather than cultural, ethnic, religious and social dimensions. More importantly the study revealed that teachers either could not adapt their teaching to incorporate the above dimensions or were unwilling to make the efforts. Indian teachers do not want to recognise any diversity in the classroom and hence did not see any need to address it in science teaching. From a research angle the study led to a framework for understanding the relationship between culture and science education within classroom settings.

Some recent studies have focused on concerns of inclusive education and argumentation related to socio-scientific issues. A study initiated in 2010, explores attitudes of parents, teachers and students towards inclusive education and aims to develop strategies for visually impaired students (Sharma & Chunawala, 2013).

Another research in the area of students' engagements with socio-scientific issues aims to probe their understanding of issues and analyse their argumentation on issues presented to them (Raveendran & Chunawala, 2013). Socio-scientific issues are science-related and at the interface of science, technology and society but have ethical/moral/social dimensions to them. A study among biology doctoral students coming from premiere institutes in science involves assessment of students' critical thinking capabilities in the context of genetic determinism. It elicited from the students a diverse range of criteria motivated by epistemic and ultimate values, and showed that they uncritically accepted fallacious claims in a popular media article. It also indicated the need to introduce such exercises in the postgraduate and undergraduate curriculum. The research program expects to develop pedagogic strategies for improving these skills.

2.5.1 Research outcomes

Some of the positive outcomes of the research studies in the socio-cultural areas are:

1. Peer reviewed research publications, expository writings, technical reports.
2. Collaborations within and beyond the Centre, at the national and international levels.
3. Research scholars motivated to integrate socio-cultural dimensions in their doctoral and post-doctoral work.
4. Influenced the direction of research at the Centre, often explicitly, as in the development of curricular materials.
5. Broadening research interests at the Centre and increasing its relevance to areas beyond science and mathematics.
6. Sessions on socio-cultural issues in science, technology and mathematics education have become an integral part of all teacher development programmes of the Centre.
7. Insights into the significant issues of equity that arise in Indian classrooms and relate to Indian teachers.

2.6 Design and technology (D&T) in school education

(Faculty: Chitra Natarajan, Sugra Chunawala; 3 Ph.D.s; 1 student to complete)

An early programme aimed to promote critical and quantitative reasoning among post school students on issues at the interface of science, technology and society. Sensitising post-school students to complex linkages between science, technology and society was the basis for the programme. The programme led to a set of books on an activity based foundation curriculum suitable for students of science, commerce the arts and humanities. It was found that post-school students had little understanding of technological artefacts and systems and their design. For post-school students to critically examine the complex relations between science, technology and society, they need to appreciate the relations of technology with the other two. They need to be exposed to design and making of technological artefacts. A study involving survey of students and teachers showed that technology is often perceived merely as objects, and not as a system, an activity or knowledge. Design is rarely associated with planning technology.

A research programme was initiated that visualises design and technology as organically linked and inseparable, and hence termed D&T education. The D&T education programme at the Centre has been rather broad based, and explicitly holds the view about design and designing – that it is an ability, like language ability, that everyone possesses at least to some degree. The programme views D&T activities as contexts for the application of conceptual and procedural knowledge from several school subjects, procedural and artistic skills, as well as aesthetic and social values. The research has been guided by theoretical issues of cognition and action, collaborative learning, multimodal communication, and concerns of socio-cultural and gender appropriateness.

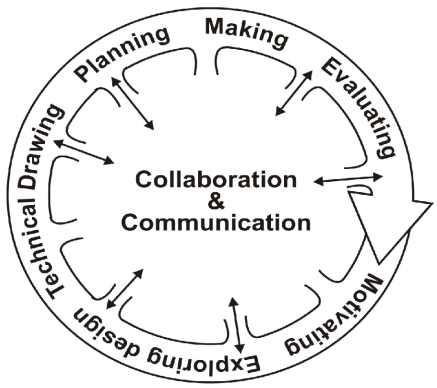

Figure 2.1: Collaboration and communication centred model of D&T education.

A framework was developed for introducing D&T as a school subject – the collaboration and communication centred D&T education (Figure 2.1). The approach shifts the emphasis from the dominant global view of technology education as being individual student's use of digital technologies to collaborative participation of student teams in designing, making and evaluating need-based artefacts and systems. The approach also helps students critique existing design and use of technology in everyday life (Natarajan & Chunawala, 2009). In view of the socio-cultural diversities of Indian classrooms, the framework included several research concerns at the Centre, some of which have been addressed. Three students have completed their doctoral work in this area.

One of the major research concerns is the development of a design and technology (D&T) curriculum for Indian schools based on communication and collaboration, and studying their implementation in schools. Socio-cultural aspects like gender and habitat are included in the design of the research. The research studies are briefly given below.

1. Surveys provided insights into views on and attitudes towards design and technology among students, teachers and professionals (Mehrotra, Khunyakari, Chunawala, & Natarajan, 2007; Ara, Chunawala, & Natarajan, 2013). These insights helped develop the intervention units among middle school students.

2. *Development of D&T activity units for students:* D&T education units were developed through classroom trials with middle school students (age 11 to 13 years) from three school settings: English medium urban school, Marathi medium urban school and Marathi medium tribal school (Ashramshaala) (Mehrotra & Khunyakari, 2007; Khunyakari, Mehrotra, Chunawala, & Natarajan, 2007).

3. *Study of the communication and collaboration strategies of students engaged in D&T activities:* Levels of communication, relations developed between members and roles played by the students within and across groups gave evidences of collaboration. One of the aspects of collaboration and communication was the

kind of talk among students during the engagement. Of the three kinds of 'talks' – cumulative, disputational and exploratory – the study found cumulative was the most frequent kind of talk in inter-group communications on the product and its design (Mehrotra, Khunyakari, Natarajan, & Chunawala, 2009). This was the case among Marathi and English language students in urban and rural settings.

4. *Study of the cognitive and affective aspects in students' engagements in D&T activities:* The nature of productions and learning through collaborative creation of objects and knowledge was another aspect of the study. Students effectively used exploratory sketches and analogies to conceptualise their design ideas: evolving from doodles that suggested known objects to newly conceptualised design (Khunyakari et al., 2007).

5. *Probing the scope for creative engagements in D&T activities:* A series of studies on middle school students' creative engagements with artefacts in suitably structured tasks, showed that they used varied handling and cognitive strategies for relating the structure and function of unfamiliar objects (Ara, Natarajan, & Chunawala, 2009) and also designed creative solutions to real world problems (Ara, Natarajan, & Chunawala, 2010). A study revealed that there was greater creativity and risk taking when students were not constrained to make. However, having to make provided students opportunities to continue to design till a working product was achieved.

The D&T education pedagogy evolved to meet several needs, including student learning and its assessment. However, conducting meaningful projects has been a major challenge for teachers. A study of teachers' ideas showed that teachers have difficulty implementing projects that are set in authentic contexts, are central rather than peripheral to school syllabi, include specific learning objectives, and integrate assessment aspects (Shome & Natarajan, 2013). The study led to research on development of a model for professional professional preparation of teachers to conduct projects in general and for D&T education, in particular. A study in this context explored ways of implementing project based learning (PBL) in collaboration with teachers through teacher development workshops dynamically planned for the purpose. The study analysed assessment rubrics by collaborative teacher groups generated to assess processes as well as products, and suitable for self and peer assessment by students. Teachers' rubrics evolved progressively through a series of structured interactions.

2.6.1 Future research plans

Future research is envisioned at the interface of culture, thought and technology. Culture would include aspects like language, gender, ethnicity, socio-political milieu, and local (indigenous) knowledge. Thought and cognition would deal with ways of thinking, reasoning, values, aesthetics, intentions, desires and wants. Technology will be examined in terms of its manifestations and practices of engagement. The overall aim is to help students and teachers appreciate enabling, inclusive, and sustainable technologies, and critically evaluate existing and new technologies. One of the needs for expanding the D&T education project for implementation in classrooms is the development of teachers' capacities to link science, technology and society projects in the their classrooms. These ideas will guide future research in this area.

1. Socio-cultural aspects of D&T learning (Natarajan, 2007).
2. Designing Environmentally Sustainable Solutions (DESS), which involves developing activity modules/ projects that involve design and making while integrating ideas about resource conservation and sustainability. The study will also include addressing issues of appropriateness of different technologies for diverse social groups.
3. S&T Education and Diversity (STED), which involves research on understanding gender and other socio-cultural aspects of S&T among students and teachers, and development of intervention activities and materials. While the study has been initiated with regard to science teaching in the vicinity (SED), studies are planned to address these issues in different populations around the country and similar issues with regard to technology.
4. The following aspects of assessment:
   (a) Developing strategies for assessment of processes: Eg. Group and individual activities, such as in science experiments, D&T projects, project based learning, etc.
   (b) Developing models for collaborating with teachers to implement assessment strategies in classrooms.
   (c) Study of self and peer assessment among students in normal classrooms and in competitive environments.

The D&T Education research is severely limited in human resources: the research group has never included a scientific member, and has depended largely on research scholars, who have a shorter term agenda to conduct research, develop models and trial them in the field. Short term project positions pose the need of repetitive training even for routine activities. Despite the limitations the two faculty involved in the group have built a coherent body of knowledge in the area and credibility of the group in the international community.

2.7 Research publications

2.7.1 Types of publications

So far in this chapter we have described research in science, technology and mathematics education (referred to in the following text and figures as 'STME' or 'Education'). The launch of the NIUS program in 2004, with its emphasis on undergraduate science

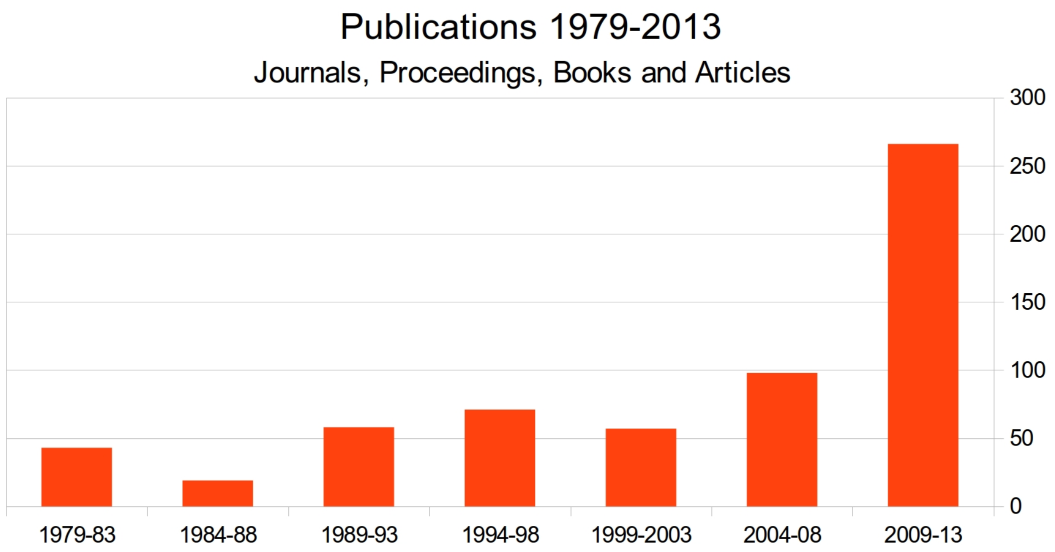

Figure 2.2: Growth of publications.

research (Section 6.1), has encouraged mainstream science publications by HBCSE members. At the same time, science education research has also been carried out as part of NIUS (Section 6.1.6. This section describes the trends in STME / 'Education' as well as 'Science' publications.

A point to note is that HBCSE's mandate includes research, development and contact programs. Hence, unlike a purely research organisation, our publications take various forms: including, apart from research papers in journals and proceedings, books and book chapters, internal and technical reports, also classroom experiences, expository writings, popular science and web publications. A gross year-wise count of all of these publications is shown in Figure 2.2. This count has increased strikingly, particularly in recent years. This increase is attributable mainly to research publications[3].

2.7.2 Numbers of research publications

Figure 2.3 shows the numbers of research publications in journals in successive 5-year periods beginning from 1978-83. Up till the last decade these numbers were quite low. Several factors have contributed to the sharp increase in research publications in the past decade. The growth of the graduate school in science education and growth of the NIUS program are two factors, both of which highlight the role of HBCSE's graduate students on the one hand and undergraduate science students mentored by HBCSE faculty on the other, in producing quality research publications. Another factor in the case of science publications is the induction of young faculty who have continued with their science research programs, in the context of NIUS or otherwise, and senior

[3]Given the range of journals that are included in this analysis (see Appendix C) the articles in them lie on a spectrum from 'research' to 'pedagogical'. The reliability of this classification is yet to be ascertained. For the intrepid archivist and the curious reader the classified list of papers on which this analysis is based is kept in the Dean's Office. – Editors

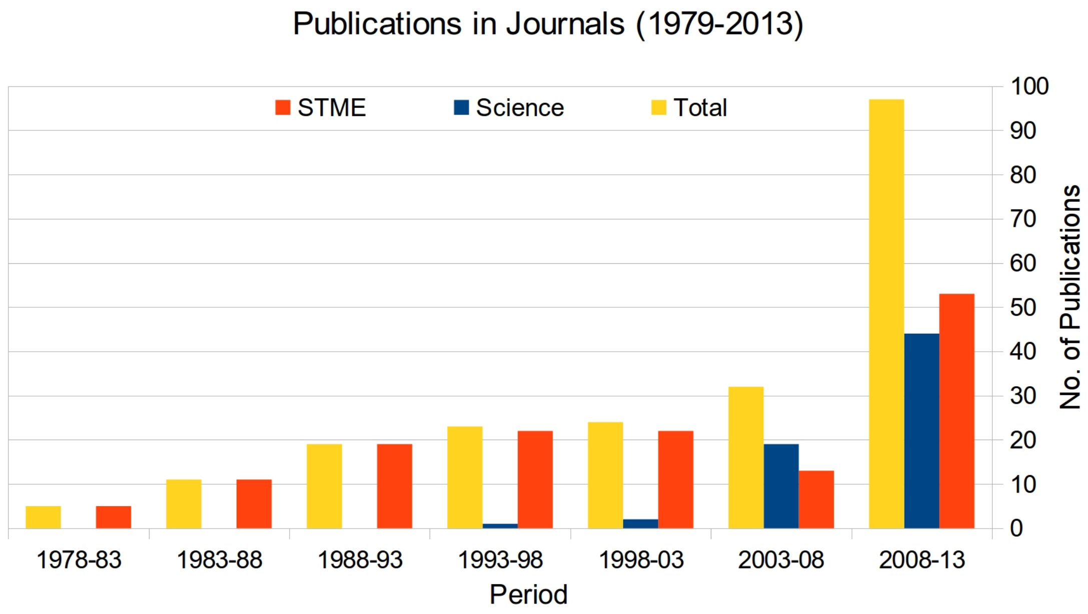

Figure 2.3: HBCSE publications in journals.

distinguised visiting faculty who have contributed in the guiding of NIUS students. The 'Education' publications in journals in the 40 years between 1974-2014 number only around 160, while the 'Science' journal publications, which began with a trickle in the late 1990s, now number about 80.

Figure 2.4 shows that there has been a concurrent sharp rise in publications in conference proceedings in the past decade. Apart from the factors given above, in the last decade there has been an increase in participation by HBCSE members in conferences in India and abroad, due to the availability of funding under the Knowledge Exchange scheme. HBCSE itself has organised a number of conferences in recent years such as, the First International Conference on Education in Chemistry (ICEC-2010), epiSTEME-4 in 2011, epiSTEME-5 and the 20th International Conference on Conceptual Structures in 2013 (refer Section 2.10 and Appendix B). A good number of the 'Education' publications in this category are those presented in the epiSTEME conferences' (Figure 2.4).

2.7.3 Impact factors and citations

A standard measure of the quality research publications is the impact factor (IF) of the journals in which the papers are published. The two Tables in Appendix C list the 'Education / STME' and the 'Science' journals in which HBCSE members have published papers, in descending order of IFs. The numbers of papers in each of these journals is listed. A citation analysis of these papers was also done.

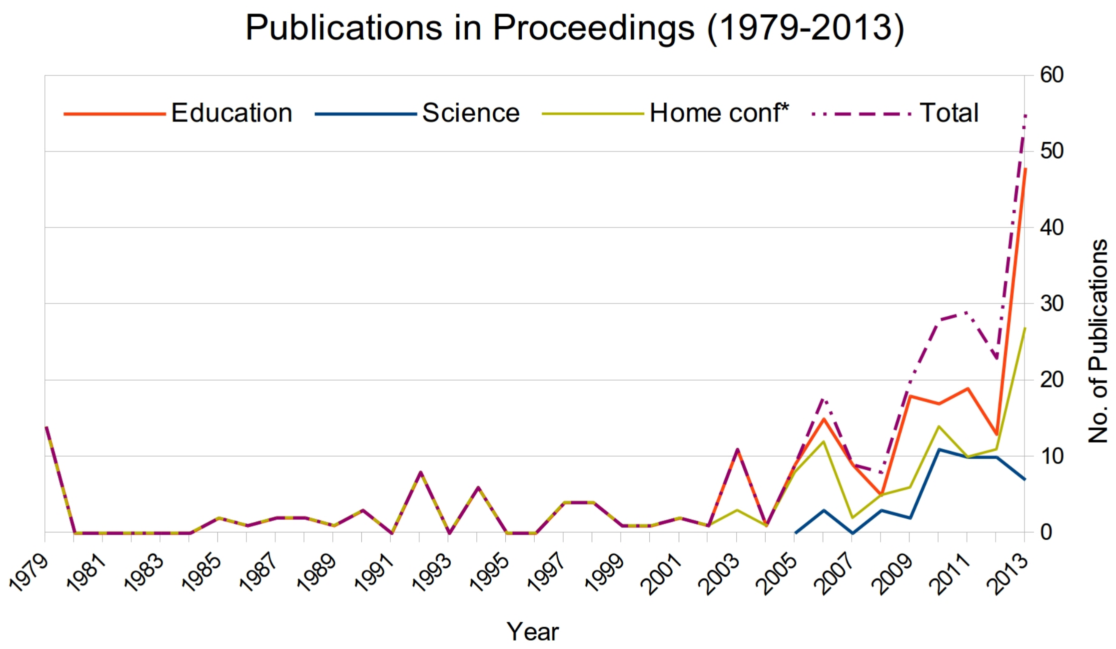

Figure 2.4: HBCSE publications in conference proceedings.

STME / Education publications

Of the 62 journals in which HBCSE's STME papers are published only 18 have an assigned IF (which ranges from 0.27 to 2.552). Over 35-40 years a miniscule 53 papers have been published in these 18 journals. Of the 53, 29 papers are published in journals with IF $>$ 1.3; 13 of these being in the International Journal of Science Education (IJSE) with IF of 1.32. Other journals with assigned IF in which a fair number of papers have been published are, Resonance, European Journal of Physics and American Journal of Physics. The majority of these 53 papers are published in the last decade, after science education research became an important mandate of HBCSE. As noted earlier some science education research is also carried out as part of the NIUS program (see Sections 6.1.4 and 6.1.6), hence some of these STME papers have been published as part of the NIUS program.

Another measure of quality of research publications is the number of citations, particularly those that are not self citations. Of the total 144 STME journal publications up to March 2013, only about 25% have been cited.

Figure 2.5 shows the citations of all journal papers published in successive 5-year periods up to March 2013 (data as of February 2014). The total number of citations of STME publications being quite small, the fluctuations look apparently (proportionately) large. Figure 2.6 summarises citations for all the publications. Leaving aside 107 of the 144 publications that are uncited, the largest number of (cited) papers fall in the citation range 1-4.

Among the 16 highest cited publications of the Centre (all papers with more than 10 citations, not including self-citations), 9 are in the science category and 7 in the STME category.

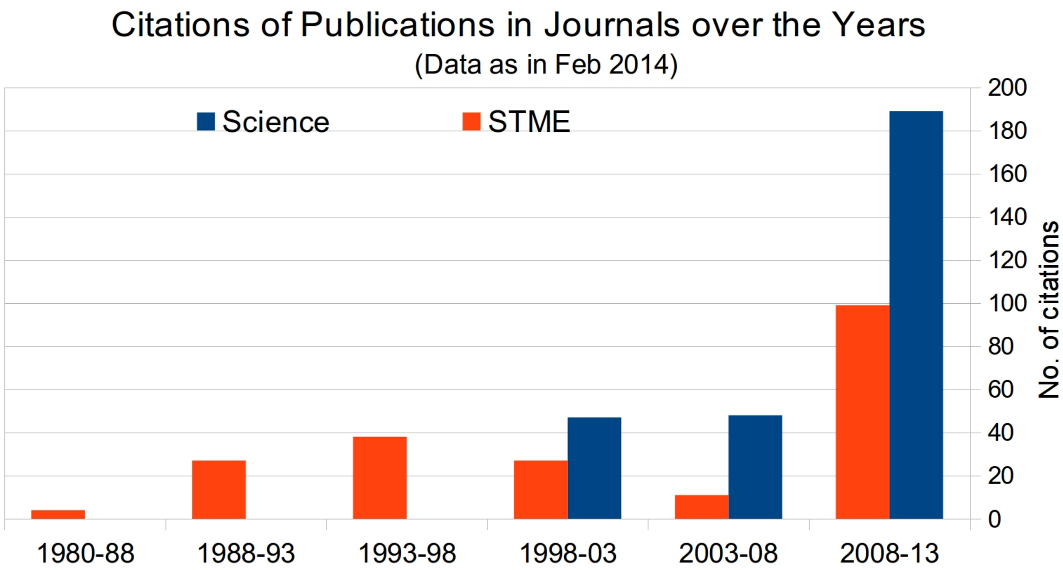

Figure 2.5: Citations of publications in journals from 1980 to 2013.

Table 2.1: Impact of journal publications (as in 2013). IF = Impact Factor

STME (144 papers)		Science (65 papers)	
IF	No. of Citations	IF	No. of Citations
NA	22	NA	0
>2	3	5 to 6	78
1.5 to 2	8	4 to 5	42
1 to 1.5	154	3 to 4	49
0.5 to 1	11	2 to 3	69
0 to 0.5	8	1 to 2	29
		0 to 1	17

Over the years only 7 STME papers (all published in IJSE) have accumulated citations more than 10: three on conceptions in Galilean relativity (Section 2.3.2), one on understanding of health (Section 2.5) and three papers in a special issue on visual and spatial modes in science learning (Section 2.3.3). Two of these papers are in the last bin of '20 and above' citations in Figure 2.6. The highest citation of an STME publication till date is 31 (excluding self citations), which is for a review paper on visual and spatial modes in science learning.

The distribution of the total 206 STME and 284 Science citations according to the Impact Factor of the journal is given in Table 2.1. Most of the STME citations are in the IF 1-1.5 range, which happens to be one single journal (IJSE).

Apart from journal publications, some of the book chapters written by HBCSE members and papers in STME proceedings are also cited. A total of 4 book chapters and 12 papers in conference proceedings are cited with 1-4 citations each (up to 7 as of

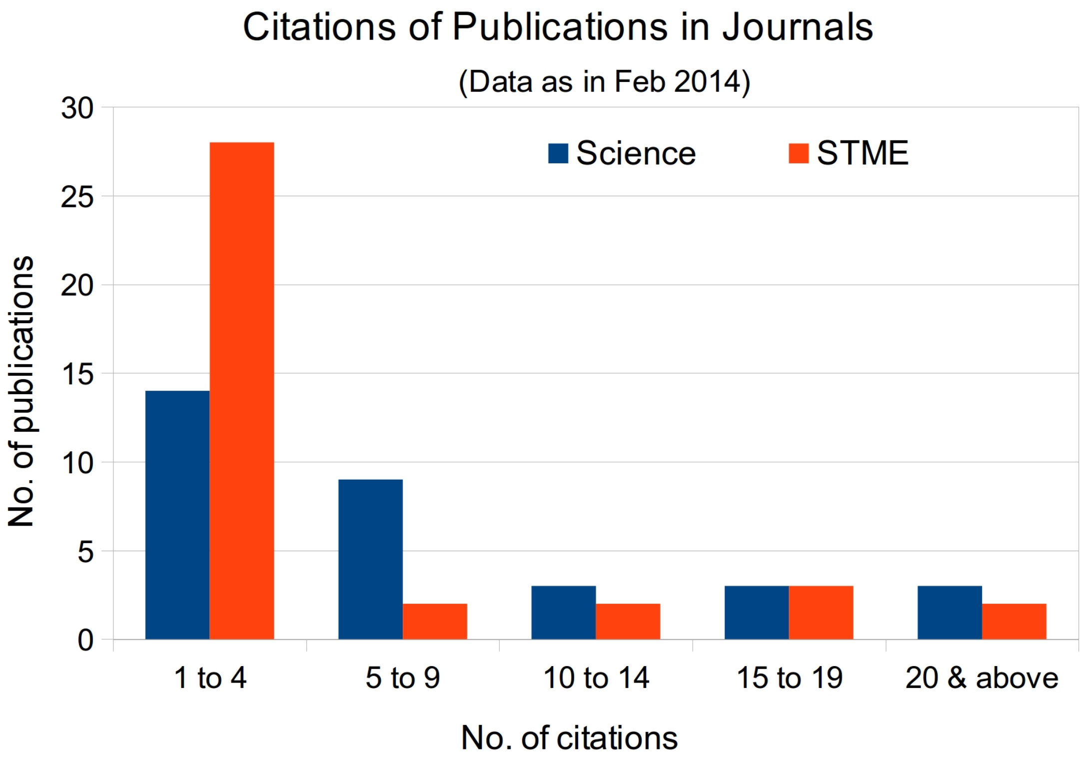

Figure 2.6: Citation pattern of publications in journals (1980 to 2013).

September 2014). These conferences are well-regarded in the community, for example, Psychology of Mathematics Education (PME) and Mathematics Education Research Group of Australasia (MERGA). Our effort should be for HBCSE's own epiSTEME conference to join this league.

There are several issues with our publications priorities and also with this IF and citation analysis which HBCSE faculty have discussed in the course of this self-review. About half of the total number of STME journals in which HBCSE members have published are Indian journals which typically do not quote an IF (see Appendix C, Tables C.1 and C.2). 'Resonance' and 'Current Science' are the two exceptions. The Indian journals not citing an IF may include a few which have a reasonable peer review and editorial system in place: an example is 'Contemporary Education Dialogue'. A quality Hindi magazine for teachers called 'Sandarbh' publishes expository articles, some of which may be comparable to 'Resonance'; the former does not have an IF and is considered a magazine rather than a journal while the latter does and is considered by us a journal. None of the above cited journals is accepted by the Subject Board in Science Education as qualifying to support submission of a Ph.D. thesis while 'School Science', a journal for teachers published in UK, which has no IF, has so qualified. These matters need further discussion in the faculty.

Research needs an international peer group, a fact that is often not acknowledged in our country. Educational research carried out as part of M.Ed. and Ph.D. dissertations in education departments is often limited to no-impact journals and hence lacks adequate peer review. Regarding publications in Indian journals one viewpoint states that, while it is important to publish research in peer reviewed, high impact journals, it is equally important to publish HBCSE's work in national journals as these would be accessible to Indian researchers, teachers and educationists. In fact HBCSE being a unique centre for science and mathematics education in the country, we do have a responsibility to support promising indigenous journals. On the other hand, it could be argued with some justification that a rigorous peer review process is essential to validate research. Popularisation and dissemination of research is important, but it should be done after peer review, and may also be effectively done through more popular media.

It is striking that up till now some of the higher impact STME journals like, 'Journal of Research in Science Teaching' (IF = 2.552), 'Science Education' (IF = 2.382), 'Journal for Research in Mathematics Education' (IF = 1.552) and 'Journal of Technology and Design Education' (IF=0.339), have few or no publications from HBCSE members. These journals happen to have more exacting review processes hence could provide an incentive to improving the rigour of our publications. This situation may come about in the near future as students and faculty do have papers currently under review with these journals.

Science journal publications

The science journals in which HBCSE members have published research papers are shown in Table C.3 in Appendix C. As seen in the figures and tables cited in Section 2.7.3, journals in this list typically have high IF as compared to the STME journals. Of the 41 science journals in which HBCSE members have published 82 papers (up to March 2014), only 8 journals, having 11 papers, do not quote IF. For the remaining journals, the IF ranges from 0.34 to 6.733, an exception being 'Science', with an IF of 31.027. Half of the science publications are in journals with IF above 3.

Citations of science publications by HBCSE staff have often been higher than those of STME publications, with about 48% of the 82 science papers being cited. One of the papers, published in 'Astrophysics and Space Science' has a citation as high as 60 (excluding self citations). Another astrophysics publication in the journal 'Science' with 58 authors has been cited more than 120 times, but including self citations. In general, the more numerous and highly cited science publications come from areas of research, like nuclear physics and astrophysics, that are well-established in TIFR and internationally.

2.8 Convergence and growth of STME research at HBCSE

2.8.1 Characterizing STME research trends at HBCSE

Many of the research studies done at HBCSE from the beginning till date have emerged from intervention efforts and have remained close to the contexts of intervention in terms of the research questions posed and the research methodologies adopted. The intervention contexts include curricular or pedagogical reform and teacher development. Curricular and pedagogical studies of middle school science, mathematics education research on learning strands in the middle school, research on teacher development, D&T education research, PER studies on relativity and procedural understanding of experiments, the VSR study on elementary astronomy and DNA structure, and the research on critical graphicacy are examples of studies situated in or close to intervention settings.

Many of these studies have drawn on frameworks and methodologies derived from cognitive science or socio-cultural studies, and to a lesser extent from history and philosophy of science. Some of the studies are located away from the actual sites of classroom teaching or teacher education workshops. This group includes studies on students' alternative conceptions in several topic areas, the construction of concept inventories, studies of concept mapping, diagrammatic reasoning, learning with multiple representations and socio-cultural studies of students' and educators' beliefs and attitudes.

The current trends of research efforts at the Centre indicate that both kinds of studies are likely to grow and flourish. The two kinds of studies present distinct challenges in terms of thematic frameworks and methodology and also present different kinds of opportunities for convergence.

2.8.2 Intervention based studies

Thematic convergence: The intervention-based studies assume a broadly constructivist paradigm of learning, which resonates with the national consensus as reflected in Indian policy documents on school education. The assumptions underlying these studies include an acceptance of inquiry-based learning approaches in STM education, importance of active exploration and experimentation by learners, the central role of discussion in learning and fostering students' thinking and reasoning. This broad shared vision of classroom learning calls for an understanding of a teacher who has deep knowledge of content related to the work of teaching, who is sensitive in responding to students' thinking and is resourceful in the use of pedagogical strategies and devices. These assumptions underline a shared vision and commitment concerning the direction that STM education must take in the country, that provides the energy for a range of research, development and intervention efforts at the Centre.

Intervention based research studies at HBCSE across a range of topics draw on some common theoretical constructs and frameworks as suggested by the remarks made above. Some examples are (i) constructs to describe and analyse classroom discourse, students' questioning, peer interaction and collaboration, (ii) constructs to describe students' understanding and thinking including alternative conceptions, (iii) organization of topics in the curriculum, and (iv) teacher knowledge, beliefs and practices.

Methodological convergence: Many of the intervention-based studies are located in complex settings, where researchers come face to face with actual processes and sites of teaching and learning. The methodologies are variously characterised as 'conjecture-driven design' or 'classroom design studies' and 'design-based research'. The studies often involve analysis of classroom or workshop interaction, relying on audio or video data, or detailed observation records. Such analysis generates a shared need for frameworks and techniques of data collection and analysis, which has led to informal sharing and learning opportunities among research scholars working across topic areas. These interactions should lead to deeper reflection on the coursework organization with a view to developing greater understanding and power in terms of the methods used for research. Some of this reflection has already begun.

2.8.3 Studies drawing on cognitive or socio-cultural paradigms

Thematic convergence: Many of the cognition-focused research studies at the Centre draw on Piagetian and Post-Piagetian paradigms of cognitive science. Some of the conceptual areas of convergence include (i) conceptual analysis of tasks (ii) alternative conceptual frameworks and (iii) connections between students' developing understanding and historical notions in the development of science. More recently, new ideas from cognitive science, such as visuo-spatial reasoning, multiple representations and distributed cognition have also informed research studies at the Centre. Research studies adopting broadly socio-cultural paradigms draw on ideas of culturally situated knowledge, social studies of science, issues linking science, technology and society (STS), socio-scientific issues, scientific temper and scientific literacy.

Methodological convergence: Some of the main research tools used in this set of studies are interviews and adaptations of clinical interviews and experimental methods drawn from cognitive science. Such tools have been used in both science education and mathematics education research at the Centre. Other tools include surveys and diagnostic assessment tools. Students' and teachers' beliefs have been probed through questionnaires as well as interviews in several studies across topic areas. VSR studies have focused on the analysis of diagrams, gestures and models. As in the case of intervention-based studies, research scholars have informally shared methodological insights and learned from one another where overlaps and similarities exist in their research tools. Reflection on how to build on such convergence needs to be carried forward.

2.9 Graduate programme in science education

HBCSE has had a Ph.D. programme in Science Education almost from its inception, though the number of graduates in the early years were few. Between 1976 and 1992 the Ph.D. degree was awarded by the University of Pune (just four Ph.D.s were awarded during this period) and between 1993 and 2001 by the University of Mumbai (three Ph.D.s were awarded in this period). With the attainment of Deemed University status by TIFR in 2001, Science Education was recognised as an important subject, with a

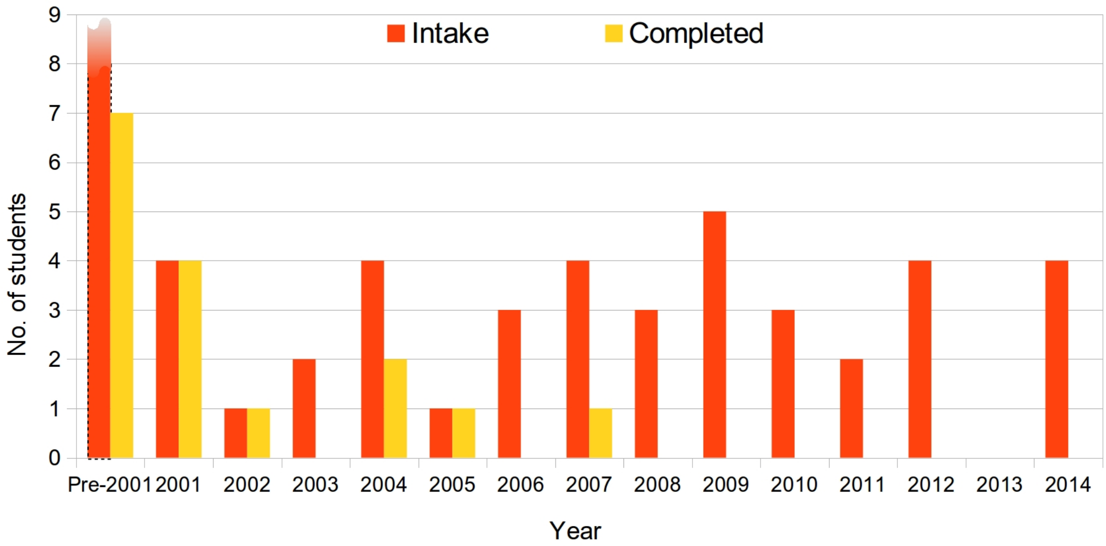

Figure 2.7: Ph.D. in science education (intake and completion).

separate Subject Board devoted to it, and the first batch of Ph.D. students in the area registered in 2003.

Research in science education calls for multidisciplinary knowledge of subjects foundational to STME, combined with a deep understanding of education as a field of reflection and action. HBCSE as an autonomous Centre under the TIFR inducts academic members with multidisciplinary expertise, educational experience and understanding of factors that affect education. Its graduate programme structure aims at training persons with a high level of expertise and ability, who can assume leadership positions in bringing about change in education in a variety of functions: as researchers, as educators, as teacher educators and as designers of educational environments and resources. Research Scholars admitted to the Graduate School in Science Education go through a programme of courses and field work or project work, followed by a dissertation on an approved topic of research leading to the degree of Ph.D. in Science Education of the TIFR. As an area for the Ph.D. degree, the Subject Board Guidelines state that Science Education is to be interpreted broadly, to include mathematics education, technology education and other allied areas.

Practising science and mathematics teachers and teacher educators are encouraged to apply for the program. At any time there are between 15 and 20 research students at various stages of research or course work. Figure 2.7 indicates the intake and status of graduation of the students at HBCSE. The procedures and rules help ensure a high quality of Ph.D. Thesis in Science Education from each student, that is locally grounded, at the same time meeting international standards. An overview of the research areas addressed so far is provided by a list of thesis titles and tentative titles of accepted research proposals presented in Appendix D.

The graduate school in Science Education is at the core of the Faculty of Science Education, TIFR. Institutionally, research, teaching and mentoring done as part of the graduate school is what makes HBCSE, and its faculty members, part of the TIFR deemed university. Sustained research effort, and a healthy Ph.D. program as part of it, is needed for the continued existence of HBCSE's faculty. Over the past few years however there have been concerns raised about our sucess in attracting and retaining talented students to the Ph.D. program, and consequently also in sustaining our fledgeling research programs.

A two member committee[4] was therefore constituted to review the graduate school at HBCSE, addressing the following issues, and making recommendations for the future: (1) Admission process, (2) Graduate course work and qualifying exams, (3) Dissertation proposal development, (4) Research process and research ambience, (5) Student motivations and experiences, (6) Drop-outs at early and late stages and possible reasons, (7) Job prospects for students and future possibilities after leaving the programme. This committee met with research scholars and held detailed discussions on these issues. A summary of the findings and recommendations of the committee is given below, with some further notes, which are based on inputs from faculty members. Detailed discussion on these matters is yet to happen in the faculty.

2.9.1 Admission process

One of the concerns motivating the review was whether the admission process was targetting and recruiting the most suitable candidates for the programme. The interviews revealed that a majority of students who were admitted to the programme were already aware of HBCSE and had interests that broadly matched with the Ph.D. programme. However, it is known that many students outside HBCSE are not aware about the Centre and its work. The programme needs better publicity, particularly in colleges offering Bachelor's and Master's programmes in education (as well as in those offering programs in science and technology / engineering). The publicity could be achieved by targeted advertising as well as by building contacts with such institutions. More information should be available on the website on what the programme offers in terms of coursework, research and post-research opportunities. The experience of the written exam and interview was positive for most students, and the review recommended continuing with the present arrangement broadly with some minor improvements.

(Note: Even small initiatives may lead to detectable effects. For the 2014 admissions the Research Scholars and alumni contributed to making and delivering a publicity presentation, *Science Education Research - What is it, why do it?*, which was viewed on the website by potential candidates - as reported by those who appeared for the admission interview. Also, a small change in the marking scheme of the entrance test was implemented to reward accuracy over speed, which may have positively affected selections. Such initiatives need to be pursued consistently and followed up with an analysis of the student admission data over a longer term.)

[4] The members of the committee were K. Subramaniam and Sanjay Chandrasekharan.

2.9.2 Course work

Research in science education requires inter-disciplinary training and preparation. The burden of such preparation is mainly carried by the coursework. Hence the graduate coursework in science education has multiple objectives which include orienting students coming from diverse backgrounds to work in education, developing an understanding of education through appropriate theoretical perspectives and experience, along with research skills and a critical commitment to educational change. The present coursework needs to be strengthened to address these multiple objectives through including the following: core courses that expose students to the contributions of foundational disciplines such as sociology and philosophy to education, more focused courses on core research skills such as of gathering and analysing data, making an argument, and writing, course on education policy in India, and introductory courses on STME research.

It is important to align the coursework broadly with what is recognized countrywide as contributing to the preparation of teachers and teacher educators, especially through inclusion of a component of teaching in schools and/or colleges. A suggested course programme is under discussion. Courses need to include diverse pedagogical and assessment modes, and assessment needs to be strengthened. A mechanism needs to be in place for both open and confidential feedback from the students that can be used for "course correction".

2.9.3 Fieldwork, qualifying exam and proposal

The qualifying exam and proposal writing are critical stages in working towards a dissertation. The following recommendations were made by the committee with a view to aligning the qualifying exam more closely with the progress towards the proposal stage. This is expected to shorten the time needed to prepare the proposal and to make the process more efficient. A comprehensive examination based on one or two research based term papers drawing on the coursework should be held at the end of the first year. (Note: At present this is a take-home exam based on course work in the first two semesters.) At this time, the student is expected to formulate a broad area of interest and the subject board, in discussion with the student, identifies a Thesis Advisory Committee (TAC) and assigns a prospective guide. TACs have been functioning since June 2013. The review committee has proposed that the TAC be formed at the field work stage, rather than waiting till the proposal stage.

The second stage of the examination is recommended to be based on a viva-voce and/or seminar presentation, that is focused on the fieldwork and the literature relating to the research proposal. The third stage should be a presentation and defence of the research proposal. It is proposed that the fieldwork and the proposal be seen as related and as an integrated stage in the preparation for research, to be taken up after completion of the comprehensive examination at the first stage. Proposals need to be stronger in their coverage of literature and methodology, than they are at present, and need to be clearer on operational aspects.

2.9.4 Research (dissertation) work

The review recommended strengthening support structures available to research scholars during the phase of dissertation work through regular meetings of the TAC, and more active mentoring by senior research scholars. It was suggested that the Annual Research Meet (ARM) be organized as a student conference and that the review process for the epiSTEME conference (where most students submit papers) be strengthened. The review committee proposed that, in the case of many research studies, it may make more sense to address the publication requirement based on the field work or literature survey, before data collection and analysis for the main study. It suggests that focusing on a journal publication at the time of data analysis and thesis writing may lead to efforts to publish results prematurely. It was also recommended by the committee that the present mandatory requirement of a paper accepted in an international peer-reviewed journal be made more flexible taking into account a variety of publication platforms.

(Note: These proposals will remove the prior peer review requirement for the main thesis work, which may not be advisable or acceptable by the norms. Given the current unsatisfactory impact and citation record of HBCSE's publications (Section 2.7), the recommendation of flexible publication requirement too is highly controversial. Any proposed change of norms must protect and improve the quality of research.)

It was also recommended that HBCSE direct more efforts to hire post-docs with a Ph.D. in science education, who can form a much needed bridge in the academic space between faculty and students. An important factor which limits the number of students who can be admitted is the skewed distribution of Ph.D. students among the faculty and availability of faculty for Ph.D. supervision. At present, several faculty members supervise no Ph.D. students, while others have multiple students. This situation needs to be addressed on an urgent basis.

2.9.5 Facilities at HBCSE

Many students spoke to the graduate school review committee positively, about the ambience of freedom at HBCSE and appreciated the academic inputs that they received from the faculty. Some students mentioned the reputation enjoyed by HBCSE and the manner in which they were treated by people outside. The facilities missed the most were good and easy access to medical care, and married accommodation with access to a good kitchen or pantry.

2.9.6 Prospects on leaving the programme

For most students, academic positions with the possibility of research were the top placement preference. Some students preferred to take up a teaching position in a school or college. Other preferred job options were teacher education, post-doc positions, activism and work on using technology in education. The question of job opportunities is brought up again in Section 2.12 and Section 8.4.7.

Several students who joined the Ph.D. programme over the years have dropped out with most dropping out during the coursework stage. In the years prior to the formation of the Deemed University the rate of dropouts was extremely high. Only 7 Ph.D.s were awarded to students during these 30 years of whom 5 were recruited in faculty positions at HBCSE. From 2001 to 2014 forty students joined, of whom 6 dropped out at an early stage and two at a late stage. Nine of them have completed their Ph.D.. These slow rates of completion are a deterrent for prospective students.

The reasons for dropouts will need more probing through discussion with those who decided to do so. The committee felt that those who wished to opt out of the Ph.D. programme may be given the opportunity to obtain an alternative degree such as M.Phil. or M.Sc.Ed. by completing suitable coursework requirements. A full discussion of pros and cons is needed here, and past experience at other places considered.

2.10 Conferences and seminars

Several National and International Conferences have been held at the Centre. These are listed in Appendix B. The epiSTEME conferences are organised biennially by the Homi Bhabha Centre for Science Education since 2004. These interdisciplinary conferences have internationally acclaimed scholars reviewing the field in foundational areas of cognitive, pedagogical, historical and socio-cultural aspects of education as well as the domains of science, design and technology and mathematics education (http://www.hbcse.tifr.res.in/episteme). Proceedings and reviews of these conferences have been published.

HBCSE has played a leading role in the National Initiative on Mathematics Education (NIME 2011-12), aimed at preparing a report on the status and outlook of mathematics education in India for the National Presentation by India at the International Congress of Mathematics Education (ICME-12) in 2012, the most prominent international gathering in mathematics education held once every four years (Section 2.4.4).

An International Ceneference on Education in Chemistry (ICEC) has been initiated by the Association of Chemistry Teachers (ACT) in collaboration with HBCSE (Section 6.1.7). The target group for these conferences is college and university teachers of chemistry. A forthcoming conference in this series will be focused on chemistry education research.

These are positive developments. A matter of concern and perhaps a symptom of an underlying problem, is that we have not been able to establish a regular system of faculty seminars. The occasional seminars at HBCSE are mostly delivered by visitors. Research scholars deliver talks at the Annual Research Meet and present papers at epiSTEMEs. In the past year the olympiad faculty took a positive initiative to present problems from the international olympiads, as part of the NIUS seminar series (Section 6.1.7). Presentations by faculty on their own R&D work are needed now, to build a peer group at the Centre. This issue should be addressed collectively by the faculty.

2.11 Impact and relevance of the science education research programme

The numbers, impact factors and citations of our STME journal publications (Section 2.7) have shown an upward trend in the past decade. There has been some recognition of our research contributions. Yet we have a long way to go to become recognised internationally as a centre for excellence in research and development in science, maths and technology education.

Our national impact can be assessed in terms of ideas and human resources developed for the country. HBCSE's Ph.D. programme is an integral part of its research and development effort in science, technology and mathematics education. This R & D effort, which is the first of its kind in the country, has over the years contributed to new thinking in school education. HBCSE's faculty have made key contributions to science and mathematics curricula and in-service teacher education at school and college levels.

Given that HBCSE's research is carried out in close-to-practice contexts, another measure of impact could be developmental, i.e. the outcomes of research in the form of materials and methods being made available to students, teachers, policy makers and the general public. There are a few countable instances of such impact.

At a national level, the NCF Science Focus Group was chaired by Prof. Arvind Kumar, then Centre Director HBCSE. Three other HBCSE faculty were members of the Focus Groups of the National Curriculum Framework (NCF) 2005, in Science and Mathematics Education and Gender Issues (NCERT, 2005). Recently, the Central Institute of Educational Technology (CIET) of NCERT has involved HBCSE in developing an ICT curriculum that involves the adoption of Free and Open Source Software (FOSS) in education. Ideas that have been developed in HBCSE's research programme are very much in consonance with the new thinking on teacher education, as reflected in recent reports.

Alumni of the Centre continue to contribute to developing and reforming teacher education courses as seen from their placement profile in Table 2.2. The epiSTEME series of conferences have had a significant impact in introducing Indian educators to fresh idea in the field, thus helping shape the current discourse on education in the country.

2.12 Questions, concerns and way ahead - Research

1. HBCSE's faculty is de facto the science education faculty of the TIFR Deemed University, responsible for conducting the Ph.D. program in Science Education. However given a variety of other responsibilities and activities, only about 5-6 faculty guide students and teach graduate courses. Some of these faculty members are now close to retirement. More young faculty need to be inducted into research in order that the science education graduate school remains sustainable.

Table 2.2: Placement record of past students with Ph.D. in Science Education from TIFR Deemed University with their current designations (December 2013).

S. No.	**Name**	**Thesis submission date**	**Current Designation**	**Affiliation (Institution)**
1.	Rakhi Banerjee	30-04-2008	Assistant Professor	Azim Premji Univ., Bengalooru
2.	Abhijeet Bardapurkar	11-07-2008	Assistant Professor	Azim Premji University, Bengalooru
3.	Swati Mehrotra	07-07-2008	Research Fellow	National Institute Of Education, Singapore.
4.	Ritesh P. Khunyakari	21-07-2008	Assistant Professor	Tata Institute of Social Sciences, Hyderabad Campus.
5.	Sindhu Mathai	08-09-2010	Specialist, Academics & Pedagogy	University Resource Centre (URC), Azim Premji University, Bengalooru.
6.	Shamin Padalkar	08-09-2010	QUEST-NGO and Visiting Lecturer	Univ of Pune – till Dec 2013
7.	Atanu Bandyopadhyay	12-04-2011	Teacher	Teaching in Bahrain
8.	Farhat Ara	13-04-2013	Research Associate	Shrishti School of Design, Bengalooru.

2. Recently the Subject Board in Science Education has begun to take account of impact factors of journals in which Ph.D. students publish their mandated peer reviewed paper. Yet there persist questions like “Is it important to publish in high impact journals?” and “Are citations a meaningful measure of the impact of our research?” Additional contradiction arises when faculty publications are accepted with less stringent criteria than are student publications.

3. A take-home point from the impact analysis of publications is that a consistent body of work by a group working in a particular area for a few years has a chance of being noticed by the community. On the other hand much of the energy of research groups comes from Ph.D. students who often develop their individual interests in their thesis work but after they leave that area may not be sustained. The small size of permanent research groups - typically a single faculty member with no scientific staff - makes it a challenge to sustain programs. The paucity of faculty seminars (Section 2.10) may also be symptomatic of the lack of sustained R&D programs.

4. HBCSE’s research and the science education Ph.D. program in particular have remained separate from the science teaching as well as the teacher education streams in the country. Academic positions in science teaching departments require a Ph.D. in the sciences. Our resources and expertise are called upon in conducting professional development programs for teacher educators or, at the national level, in the framing of policies for teacher education, yet there remains a strong resistance to accepting science education Ph.D.s without B.Ed. or M.Ed. qualifications as teacher educators. These contradictions must be resolved through dialogue and advocacy and new placement possibilities for Science

Education Ph.D.s must be created, perhaps collaboratively with other agencies (Section 8.4.7).

Chapter 3

Material development, outreach and advocacy

The development of educational materials is seen as an integral component of all HBCSE's programs. These materials include curriculum, co-curricular and popular science books, particularly in Indian languages, low cost experiments at school level, olympiad problem sets and experimental tasks, lecture notes for undergraduate students, exhibitions, websites to disseminate science, and software.

HBCSE in its early days was predominantly engaged with school-level education. Among the materials developed were linguistically simplified textbooks at the school level, co-curricular and extra curricular material, books on science experiments and mathematics activities. Many of these books were produced in English as well as in vernacular languages.

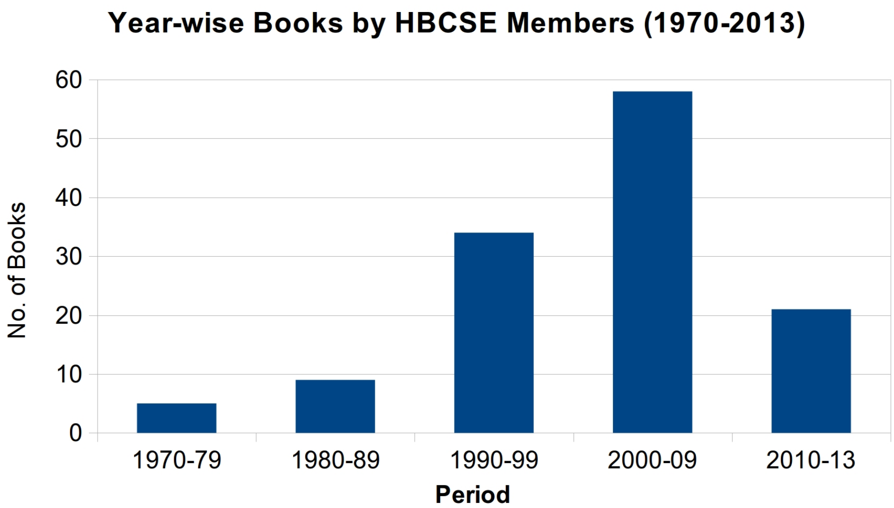

Figure 3.1: Year-wise books by HBCSE members till 2013.

Beginning in the 1980s, activities focusing on college education were initiated, at first with highly motivated college students of physics. The Olympiad program aimed at

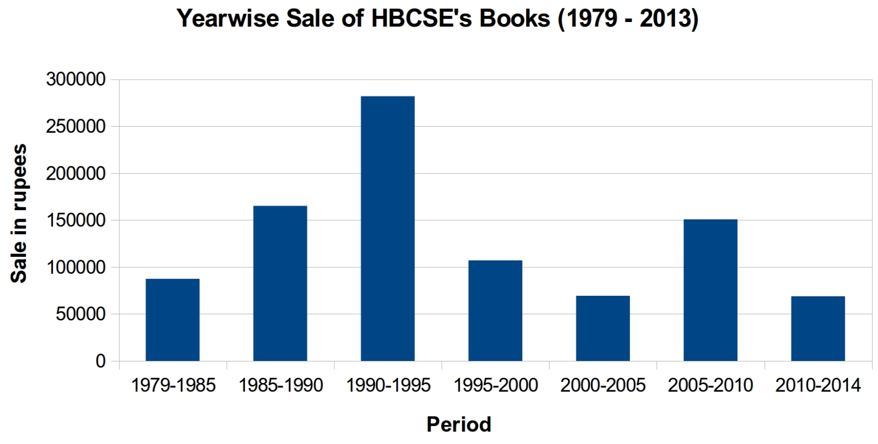

Figure 3.2: Year-wise sale of HBCSE's books till 2013.

secondary and higher secondary students was initiated in the 1990s. This important aspect of the outreach and development activities of HBCSE is described in Chapter 5. Between 1997-2004 development of the primary science and mathematics curricula was carried out. All through HBCSE continued to develop co-curricular and popular science books. A full list of books brought out by HBCSE members is given in Appendix E. The types and numbers of books each category are shown in Table 3.1 and the year-wise number of books produced is shown in Figure 3.1. The year-wise sale of HBCSE's books is shown in Figure 3.2.

These books are described in Sections 3.1 and 3.2. Websites, software, exhibitions and other resources for teachers and students are described in the later sections of this chapter.

3.1 Homi Bhabha Curriculum for primary science and mathematics

(Faculty: Jayashree Ramadas, Jyotsna Vijapurkar, K. Subramaniam; 2 scientific staff in mathematics education[1] - one past, one present; Former faculty: H. C. Pradhan and Arvind Kumar)

The Homi Bhabha Curriculum for Primary Science (Small Science) is unique in many ways: (1) its development from research, field-work and classroom trials; (2) its aims - through science to reinforce basic literacy and numeracy as well as spatial, design and construction skills; (3) its content - simple, cognitively appropriate activities and exercises linking textbook science with the child's experiences; (4) its novel, professionally designed format and style; and (5) comprehensive teacher support materials that form integral part of the curriculum.

[1]overlapping with Sections 2.4 and 3.3

Table 3.1: Books by HBCSE members in different categories.

S.No.	Category of Books (Language)	No. of Books
1	Curricular Books – Science (English)	10
2	Curricular Books – Science (Hindi)	6
3	Curricular Books – Science (Marathi)	10
4	Curricular Books – Science (Urdu)	3
5	Curricular Book - Environmental Science (English)	2
6	Curricular Books – Mathematics (English)	4
7	Curricular Books – Mathematics (Marathi)	7
8	Foundation Course (English)	8
9	Olympiad Books (English)	15
10	Co-curricular & Popular Science Books (English)	34
11	Co-curricular & Popular Science Books (Hindi)	12
12	Co-curricular & Popular Science Books (Marathi)	44
13	Co-curricular & Popular Science Books (Urdu)	6
14	Co-curricular & Popular Science Books (Eng & Mar)	3
15	Co-curricular & Popular Science Books (Gujarati)	1
16	epiSTEME Reviews (English)	4
17	Conference Proceedings (English)	7
18	Technical Reports (approximate nos.) (most English)	50
	Total Books	226

The curriculum, produced during 1998-2004, consists of textbooks, workbooks and teacher books for Classes 1 to 5 in English, Marathi and Hindi. It has received appreciation from teachers, students, scientists and educators from India and abroad, SCERTs and NCERT and has been independently translated into Urdu. In 2005 NCERT considered its publication and 3 states have considered adoption. Though these adoptions did not come about, states and NCERT adapted parts into their textbooks and the National Curriculum Framework 2005 was significantly influenced by it. Invitation as co-chair of an international working group and membership of an oversight committee on inquiry-based science education, and the TWAS Regional Award 2011 for development of scientific educational materials, have been in recognition of this curriculum. One of the authors contributed to textbooks of Andhra Pradesh and is now helping with implementation and possible adoption of the books in East Timor.

The primary mathematics curriculum (Maths for Every Child) consists of text-cum-workbooks for Classes 1 to 3, and a teachers' book for Class 3, in English and Marathi. Like the science books, albeit on a smaller scale, they have been received very well by the education community and have influenced textbooks produced by NCERT and Maharashtra state.

Some limitations: Adoption of the curriculum in any part of the government school system has remained an elusive possibility. Teachers and parents in implementing schools express concern at having to deal with a curriculum where there are no fixed answers and where rote learning or tuition classes do not help. Teacher support systems and continuing evaluation are needed, but it has remained difficult to find the human resources for these.

3.2 Co-curricular and popular science books

(Faculty: K. K. Mishra; 4 scientific staff; Former faculty: Arvind Kumar, H. C. Pradhan, S. C. Agarkar, V. G. Gambhir and others)

Development of co-curricular and popular science materials particularly in Indian languages, has been a goal of HBCSE since its inception. It is in consonance with the basic tenets of the government policies on science and education in the country and with one of the fundamental duties mentioned in the Constitution of India (Article 51A/h). The nation's dream of progress and prosperity cannot be realized unless the values of equity and inclusiveness are adopted and practised in the field of science education and popularisation.

The co-curricular books and materials brought out by HBCSE have emerged from the fieldwork and projects conducted by the Centre over the years. These books are aimed at providing quality supplementary materials to teachers and students up to introductory college level. The materials include remedial books of mathematics education, dictionaries of technical terms in science and mathematics, laboratory manuals, and user-friendly English-Hindi e-glossaries of technical terms for chemistry and biology. The series on 'How and Why in Science' developed through the effort of answering children's questions, is published in several languages and has been very popular. The Centre has also published books on Hands-on activities and novel experiments, on the joy of mathematics and its relevance in daily life. Apart from books for children, members have written popular science books for general readers. Health, gender, the new science of chaos and fractals, atomic energy, what makes water the 'matrix of life', astronomy and history of science are some of the themes of these books, These books are published by reputed publishers such as National Book Trust, India (NBT), National Council of Educational Research and Training (NCERT), National Institute of Science Communication and Information Resources (CSIR-NISCAIR), Vigyan Prasar (DST) and Oxford University Press (OUP). Expository articles have also been published in premier science journals such as Resonance. Many of these books have been translated into other Indian languages, and have gone into several reprints over the years. HBCSE members have also contributed popular science articles in the leading newspapers and magazines of the country.

The Marathi Vishwakosh project, a major encyclopedia project, is currently led by HBCSE members.In addition to print materials, HBCSE has also produced online materials. Notably, it has launched an innovative e-learning portal on science for students and teachers up to 10+2 levels (http://ehindi.hbcse.tifr.res.in). To develop and disseminate quality science materials in Indian languages, three biennial national workshops have been organized around the theme of Development of Educational E-materials in Hindi. Three books based on the presentations of the national workshops on development of e-materials in Hindi have been published by HBCSE. The website has a variety of co-curricular and popular science materials and at present consists of videos and slide presentations of lectures, books, articles, magazines, reports, documentaries, interactive questionnaires, and biographies of some Indian scientists. The Open Education Resources for Schools (OER4S) undertaken jointly by HBCSE together with

Maharashtra Knowledge Corporation Limited (MKCL) and Indian Consortium for Educational Transformation (I-CONSENT) aims at building online resources for teachers, students and parents in English and Marathi. A website consisting of learning resources on the topic of evolution together with an accompanying book has also been developed by the Centre.

Co-curricular publications resulting from the Olympiad program are described in Section 5.5.

3.3 Mathematics education - Development and outreach activities

(Faculty: K. Subramaniam; 3 scientific staff, 1 past and 2 present[2]; Former faculty: H. C. Pradhan and Arvind Kumar)

As described in the section on research in mathematics education, the work of the mathematics education group at HBCSE is aimed at identifying critical factors that need to be strengthened to improve the learning of mathematics in schools, and to develop capacity and resources that can contribute to bringing about this change. In this section we focus on the support extended to state agencies, development of mathematics education resources, outreach activities with students and teachers, and efforts to influence policy.

3.3.1 Support to institutions

A network of institutions support school education in India. These include, besides schools, institutions in each state that formulate curricula and publish textbooks, school boards that examine and certify completion of school education, teacher education institutions that prepare pre-service teachers, university departments and higher education institutions that prepare teacher educators and design teacher education curricula, and policy making and regulatory bodies that guide and regulate these institutions. The mathematics education group, like other groups at the Centre, has extended support to institutions of nearly every kind mentioned above. The mathematics education group has also extended support to short term initiatives led by the government as well as the NGO sector, under major flagship programmes such as SSA and DPEP.

The group's inputs have nearly always helped to improve the quality of work in the projects concerned. Through these support activities, members of the group have gained vast experience in working with students, teachers and educators, and understand the needs and workings of field level institutions. The projects have often served as empirical domains for the group's research, and the research findings, in turn, have enriched the inputs provided by the group to the concerned project. However, the vast

[2]Overlapping with Sections 2.4 and 3.1

institutional infrastructure for elementary education described above is even today lacking in the specialized expertise that is needed in the field of mathematics education, in such critical areas as pedagogical content knowledge, deep understanding of elementary mathematics from the teaching learning point of view, experience in implementing innovative teaching experiments, diagnostic assessment, etc. Because of this, the support extended by HBCSE tends to have a limited, short term impact. This support thus far has not aimed at building capacity in the institutions described above at a general or even a local level. This aim is a desirable, even necessary, direction for the work of HBCSE and the mathematics education group in the future.

3.3.2 Resources for teaching and learning mathematics

Over the decades several kinds of resources have been published by the mathematics education group: textbooks for primary mathematics (Class 1 to 3) and teachers' books as part of the Homi Bhabha Curriculum in primary mathematics, workbooks for remedial mathematics (Section 3.1), glossaries, posters on mathematics, video resources and web based resources. The books and posters published by HBCSE in school mathematics are popular and a number of copies are sold every year. A handbook for in-service workshops for primary teachers on mathematics was brought out in collaboration with NCERT. This is a promising channel for publication and dissemination that could be explored further in the future.

The group has developed tools to assess learning of mathematics at the primary level. These tools have been refined through several rounds of testing in schools catering to disadvantaged students in two major cities. The tools include diagnostic assessment items based on research and involve multiple modes of assessment: written, class quiz and individual student interviews. The questions probe children's understanding and have also proved useful in formative assessment (assessment that provides specific inputs to guide instruction).

The mathematics education group has also developed several courses in mathematics education that have been taught to Ph.D. students at the Centre as well as in the collaborative M.A. (elementary education) programme at TISS. The courses and resource material are published on Moodle platforms and have served as templates for similar courses at other institutions.

3.3.3 Work with teachers and students

The research and development programmes of the group draw heavily from vacation courses for students and from workshops for mathematics teachers that are organized regularly. These are integrated into the core methodology adopted for research projects, and serve to give hands-on experience with the reality of classroom teaching. Priority is given to working with disadvantaged students and teachers from government school systems.

3.3.4 Shaping education policy

Members of the group have played a role in shaping the mathematics curriculum framework and syllabus as part of the National Curriculum Framework 2005, and earlier curricula at the National level. Members of the group have been a part of the curriculum, syllabus and textbook committees at the state level. K. Subramaniam chaired the curriculum and syllabus committee for mathematics at the elementary level for the state of Maharashtra in its recent curriculum revision. HBCSE members have also served in the regional committees of the National Council of Teacher Education. More recently a member of the group has been nominated to the NCTE council, the apex body for regulation of teacher education in the country.

3.4 Gnowledge laboratory

(Faculty: G. Nagarjuna)

3.4.1 Background and objectives

The inescapable new media and the internet powered by networked computers are considered to be a powerful means of not only reaching out to every citizen, but also a means of facilitating learning. Digital technology has impacted every corner of society, and it is doing the same in education. The centre must not be a mere spectator of these trends, but participate in shaping them specifically to ensure that the educationists follow the best practices instead of following the strong market forces that are visibly driving this new media. To meet this need Gnowledge lab was conceived in the year 2000 to explore research, innovation, material development, advocacy and outreach in the emerging area of free information and communication technology (free ICT). The lab is unique in its explicit declaration to develop and use only Free and Open Source Software (FOSS) and open standards for document encoding. The lab developed through the five year plan projects of X and XI Plan with meagre investment.

The overarching vision of the lab has been informed and guided by developments in cognitive science (Nagarjuna, 2006, 2009b), epistemology (Kharatmal & Nagarjuna, 2010; Nagarjuna, 2009c), cybernetics and evolution of complex systems (Nagarjuna, 2014) and computer science (Nagarjuna, 2009a). The lab adopted constructionism (over and above constructivism and as against instructionism) as the central educational philosophy. The main objectives of the lab are (1) to do research, development, advocacy and outreach on free ICT for promoting growth of Science, Technology, Engineering, Arts and Mathematics (STEAM) in society (2) to develop and curate free software for engaging, investigative, constructionist and collaborative workspaces, called learning studios, for STEAM, (3) to do research in Structure and Dynamics of Knowledge (SDK) and develop software to support SDK research and (4) to bridge the gap between the process of doing science and science education.

3.4.2 Advocacy and outreach

As FOSS is not a perceived demand in the country, the lab conducted several workshops, lecture-demonstrations, advocacy talks all around the country and also abroad (Brazil, Saudi Arabia and Europe). The lab turned into an important hub for FOSS activities in the country. The lab hosted several meetings of FOSS communities such as Mozilla, Open Street Map, ChaloBEST, GNUKhata, IndLinux, Pandora, Wikipedia, Creative Commons, GNU/Linux users groups, etc.

We managed to influence the open standards policy of Govt of India, and ICT Education policy of NCERT. Indirect interventions by the lab prepared the way for the state-wide introduction of FOSS in education in Kerala and Karnataka. Members of the lab served on advisory committees of Indian Bureau of Standards, Ministry of Information Technology, MHRD, NCERT, CIET and other influential bodies like NRC-FOSS, CDAC, IT for Change, IT@School in Kerala, SIES, Mumbai University, Acharya Narendra Dev College, Delhi, Tata Institute of Social Sciences, Society for the Promotion of Alternative Computing and Employment in Trivandrum, Mayur School in Ajmer, K.J. Somaiya College, ICFOSS in Kerala etc. Gnowledge lab supported several organizations in migrating to FOSS.

3.4.3 Software development

Knowledge as a network of relations between objects and between properties of objects as a model of memory is used for developing a distributed collaborative knowledge base called Gnowledge Networking and Organizing System (GNOWSYS). This project is informed by recent developments in knowledge representation, network models of complex systems, distributed computing and naturalized epistemology. This flagship project started in 2001 and seven versions of the platform have been developed and released for publishing knowledge resources. The project became an integral part of the global GNU project in 2004 when it was declared an official GNU project (http://www.gnu.org/software/gnowsys/).

As an application developed for representing structure and dynamics of knowledge networks, the platform is ready for developing customized applications to support the entire lifecycle of the processes in both science and science education. The main feature that is absent in other such platforms is a complete integration of publishing online the process of knowledge creation as well as well as the outcomes. The current version of GNOWSYS release already supports collaborative creation and publication of text documents (wiki), publishing and mixing multimedia resources (audio, video, simulations and documents) on any page, tagging, organizing, semantic networking, complex documents (nested collections), course structuring and threaded discussion. Though visualization of knowledge networking and browsing is already implemented, there is further scope for improving multiple representations of the existing knowledge and its relations with others with improved support for statistical analysis of the properties of nodes in the network. The ultimate goal for this platform is to support investigative engagements for citizen science projects supporting both science and science education to meet the objective of bridging the gap between doing science and science education.

The most notable deployment of GNOWSYS is by NCERT for the National Repository for Open Educational Resources (NROER). This project is supported by the Ministry of Human Resource Development (MHRD) (http://nroer.in/). Currently Gnowledge lab is building a Massive Open Online Course (MOOC) platform for the National University Students Skill Development, in collaboration with Tata Institute of Social Sciences (TISS).

3.4.4 Learning studios DVD

Most mainstream software for education was meant to deliver content to the student or help the teacher deliver the content. The carefully curated learning studios packaged by the lab into a DVD do not fall in that category of software. These are platforms for producers and not consumers, consistent with the constructionist philosophy adopted by the lab. They support doing, designing, creating, constructing, sharing, displaying, and composing culture including language, art, science, mathematics and technology. The software bundled inside is itself created collaboratively by thousands of passionate programmers to cultivate creativity and social responsibility in society. The DVD contains carefully curated applications starting from primary school to graduate level. The DVD is distributed to students and teachers across the country. The lab conducted more than 25 hands-on workshops based on the DVD across the country. The applications are customized as a part of a free and open source GNU/Linux operating system. NCERT has adopted the DVD for nationwide distribution and developing the ICT courses for schools across the country. The Learning Studios DVD eventually included the sugar learning platform. Attempts to extend the sugar learning platform to Aakash and Prithvi tablets is ongoing.

3.4.5 Indian language computing

The lab created one of the first free Unicode font for Devanagari, called Gargi. Another font, called Samyaka, included glyphs hand-crafted by the student interns contained six different scripts of India (English, Devanagari, Gujarati, Punjabi, Malayalam and Tamil). These fonts are widely used and distributed with all GNU/Linux operating systems across the world. Translations to widely used educational application into Indian languages were periodically contributed, e.g., sugar learning platform in Marathi and GeoGebra in Marathi and Malayalam.

3.4.6 Software development experience for undergraduate students

Gnowledge lab engages the undergraduate students into a networked community. The software development activities were offered as project challenges to a large number of engineering students from across the country, though mostly from colleges in Mumbai. Students joined as interns for their final year thesis projects. The students belonged to more than 10 colleges. Some of the students won Google Summer of Code Scholarships during 2007 to 2011. Gnowledge lab worked with more than 200 students during the last ten years. The lab received occasional contributions also from Russia, Argentina, Brazil, Spain and the Netherlands.

3.4.7 Projects

The following are the major projects undertaken by the Gnowledge lab. It included SELF (Science Education Learning in Freedom) is an international collaborative project including partners from seven different countries financed by the European Commission as a part of the VI Framework. The project duration was from July 2006-August 2008. http://selfplatform.eu/ The project eventually shaped the formation of Free Technology Academy (http://ftacademy.org)

The lab took a pioneering role in supporting the pilot implementations of One Laptop Per Child (OLPC) project in Goa and Khairat in collaboration with Digital Bridge Foundation. Khairat is the first OLPC implementation in the country.

ChaloBEST began in January 2011 as a studio-based learning experiment at the Lab to make transportation data publicly available over the web, SMS, smartphones, and print media using free and open source software, geo-spatial databases, and community crowd-sourcing. In 2012 the project won the first prize in the Sankranti Transform Urban India competition held at the India Urban Conference 2011 by the Indian Institute of Human Settlements (IIHS). http://chalobest.in/

In collaboration with Sophia College for Women, a three year long project was sanctioned by DST under Cognitive Science Initiative. The project is specially designed to introduce cognitive science in undergraduate colleges. The CUBE project and the BehaviorWatch@Home project described in the section on undergraduate science education are an offshoot of this project. The context of the study was behavioural plasticity, learning and memory in animals. Several colleges and other agencies have requests to extend this project to their institutions. We plan to extend this model to about 50 colleges in the coming three year period.

3.4.8 Gnowledge lab – a critical appraisal

The lab's philosophical stand-point, inherited from the copyleft revolution, the free and open source model of making, sharing and seeking, and licensing all products under creative commons, exhibits unquestionable commitment to equity and justice. The lab has managed to build capacity in state-of-the-art of web technology and FOSS, which is enabling it to serve the country in different capacities. About three Ph.D students' work is being shaped around the activities of the lab. So far, the most impactful aspects of the lab's work are in advocacy and development.

The impact of the lab would have been more if the development work was well documented. Though several engineering students come and work in the lab, no studies have been conducted on what kind of learning happens during their project work.

The lab currently has only one faculty member and a visiting professor. Most of the human resource powering the lab come from the community including past students, current student-interns and temporary project staff. Though this limitation actually helped in building a large community around the lab, in the long run it may not sustain unless it could expand. No special provisions could be made to hire expert software programmers, despite the need and demand. Space allocated for the lab is affecting the further expansion of its activities. Despite these limitations it managed to be a hub for FOSS and ICT for education in the country.

3.4.9 Gnowledge lab – future directions

The lab would like to pull all its energy and expertise towards launching citizen science projects to accelerate the growth of scientific awareness in the country by public participation. The lab will erect a portal in this direction to support both science and science education to create functional networking among the students, teachers and researchers of the country. We have received encouragement and appreciation about the potential of studio based learning environments, and would like to continue their design and development to support meaningful learning of science and mathematics.

3.5 Exhibitions

(Faculty: G. Nagarjuna, Sugra Chunawala and others)

The exhibition on ***Science, a Human Saga*** captures the origins of science, its history, its development till the modern period. The major themes of the exhibition are: Great Leaps in Early Period; Science in Ancient Greece, Ancient China, Ancient India, West Asia; The Scientific Revolution; Science in the 18th, 19th centuries, Social Sciences, Modern Science. The history of science exhibition aims to depict several significant, but often ignored aspects of science: science as a development process, the conceptual changes that have taken place in the history of science, a process which is considered to have parallels with the conceptual changes that students undergo, science as having multicultural origins. It also aims to demystify science. The exhibition is a permanent display at the ground floor foyer of HBCSE and is open for visitors. Workshops for teachers and students have been designed around the exhibition. A soft copy of the exhibition is also available in a set of DVDs. Since (year) about (number) copies of the DVD have been distributed.

The unique permanent exhibition ***Gender and Science*** critiques gender stereotyping in science while highlighting the role of women in scientific progress. It attempts to explain the complex concepts of gender and science as well as the tenuous relationship between them. Developed to sensitise students, teachers and lay persons about the role of women in science and technology, it has representation of several women scientists from antiquity to the present, across various domains, thus highlighting the often invisible participation of women in the task of knowledge generation. It is accompanied by an exhibition booklet in English and Marathi. The exhibition is a regular feature for students, teachers and student teachers who visit the Centre.

3.6 Print materials – an appraisal

HBCSE's material development and outreach programs have expanded significantly over the years. New dimensions have been added such as technology education, Olympiad selection and training and initiatives at the undergraduate level. HBCSE's advocacy efforts now have found a receptive space at the National level. In recognition of its contributions, there are ever growing demands for the Centre's outreach contributions. It is important however to identify which dimensions and types of activity are most effective and sustainable for a small Centre in the long run.

3.6.1 Curriculum books – limits to outreach

The curricular materials at the primary level produced by HBCSE are widely acknowledged to be of high quality. One measure of the program's success is the number of books that have been sold, or are in use in schools across the country. Another measure is the extent to which HBCSE's work influences the science and mathematics curriculum and textbooks nationwide, through advocacy and consultation with statutory State and National bodies. On both these counts, the curriculum books have met with some success. The english versions of the *Small Science* students' books have sold more than 15-17,000 copies each from the time of their first publication. However, direct use of HBCSE's curricular material has constraints that are inherent to the school education system in India, where schools are mandated to use "official" state-produced textbooks.

There are also limits to the extent of influence of this material on state produced textbooks and curricula. Even when our curricular material serves as a resource for agencies that write and prescribe textbooks, often only activities and exercises are adopted, and the cognitive & pedagogical underpinnings are lost. The portions adapted retain a superficial similarily to the original but lose out on the essence. The intellectual challenge also gets compromised in mainstreaming of the content. To cite one example, a chapter titled 'Fun with Air' in the Class 4 *Small Science* books has an activity in which students classify musical instruments as producing music by blowing, beating or vibrating strings, and place their names into a Venn diagram. In the NCERT adaptation of this activity for the same class, the classification remains but the intersections between categories are removed from the Venn diagram.

3.6.2 Curriculum books – way ahead

The curriculum program at HBCSE has the advantage of access to resources and well qualified researchers and staff, is crucially enhanced by field experience and fine-tuned through classroom trials. It is a dedicated curriculum development work, often long term, something most other agencies cannot afford to do or are ill equipped to do. Hence one of the issues that the Centre needs to be address is whether and how some of these capacities and processes that are factors in the production of high quality curricular materials can be built into the textbook production by government agencies. Development takes years, but the typical time scale of the government agencies is 6 months. Continuous R&D, including testing of materials, is needed to be done in collaboration with NCERT, SCERTs, DIETs, DRCs, and with participation of resource centres in Universities.

The popular science and co-curricular books produced by the Centre have been growing and have been received very well as indicated by the number of books sold (see Figures 3.1 and 3.2). Although these books have enjoyed a good reputation, at present no clear review process exists for the Centre's own books. It may be desirable to set up a review process by independent experts. The number of books sold by HBCSE are much smaller than those sold by outside publishers. Hence, it may be more effective for HBCSE to publish its material with reputed publishers, and where possible, through government publishing agencies. The Centre also needs to evolve ways of enabling booksellers to sell its own publications. The Centre has adopted a policy of releasing its curricular material in primary science under the Creative Commons licence. Such open access modes of publishing need to be explored for the mathematics curriculum books and for other types of publications as well.

Like many of the on-going projects of the Centre, several of the development and outreach programs of the Centre draw on temporary project staff. These project appointments are currently for a maximum of 3 consecutive years. Unfortunately, when long term projects have to work with short term personnels, problems of lack of continuity and time lost in retraining can cause setbacks.

Chapter 4

Teacher education

(Faculty: All faculty members at HBCSE contribute to teacher education programmes.)

In-service teacher education has formed a continuing strand in all of HBCSE's programs since the centre's inception. Broadly the approach has been to enhance content and pedagogical techniques, introduce inquiry and experimentation and relate science and mathematics to life. Importantly, the teacher education workshops are seen as a means of generating and developing instructional materials and methods and also as a context for research. This approach to teacher education or "orientation" has evolved over the years, and must continue to do so, through a continuous process of documentation, reflection and learning.

4.1 Early model of teacher education

The early model, followed in the 1970s till the 1990s, was to identify a well defined group of schools and/or teachers and to hold sustained orientation programs with them over a period of typically about 3 years. Concurrent developmental work was carried out as part of these projects which were largely conducted in rural areas of Maharashtra (Table 4.1). The first of these projects was taken up in 1975-78, with 15 rural primary and middle schools near Khiroda in Jalgaon district. Simultaneously a similar project, in science education was conducted at the secondary school level in the Bombay Municipal Corporation (BMC). Interestingly at the secondary school level, the demand from the school teachers and the BMC school management was not for science, but for mathematics and English, two subjects which in 1975 had led to 100% failures at the SSC exams.

The project mode of functioning continued till the 1990s as seen in Table 4.1, covering rural or municipal schools in far-flung areas of Maharashtra like Satara, Chikhaldara, Surgana, Dahanu, Ramtak, Solapur, Thane, Rankol and Nashik. Some of them involved orientation not of teachers directly but of resource persons or Master-Trainers. An orientation program directly aimed at science and mathematics teachers of the residential “ashram schools” for tribal children was also carried out. The sustained interactions in these projects enabled some follow up at teacher and school levels, at least over 2-3 years. Some of the projects involved collaborations with local organizations. The projects, as a whole, served to build a team spirit and a shared sense of social commitment among the HBCSE staff, across the faculty, students, scientific and administrative staff categories. The projects resulted in HBCSE’s gaining rich and varied field experience at the primary and secondary levels of education, in rural, semi-urban and urban areas. The conceptual framework underlying this work encompassed role of language in cognition, classroom interactions and socio-cultural issues. Yet the research carried out in these projects was limited in reach, and follow-up was difficult to maintain.

Material development was one of the main aims of this first phase of the sustained projects. In fact, much of the stimulus for material development which happened in the later years like, kit development, remedial mathematics and Homi Bhabha Curriculum for Primary Science (described in Section 3.1), came from these early projects. However the extensive nature of the field work coupled with limited staff strength left little time for testing and developing materials in the course of the projects. Despite the limitations there were some achievements in this regard as indicated in the last column of Table 4.1.

4.2 Later models of teacher education

From the 1990s the field projects were gradually phased out. In their place some organizations were identified who were already running projects in rural and relatively less privileged schools. Teacher orientation was carried out with these groups, which included resource persons, master trainers and district/state level representatives. Collaborating agencies in these later projects have included, the Atomic Energy Education Society, Bombay Municipal Corporation, UNICEF, Pratham, Bombay Association of Science Education, Marathi Vidnyan Parishad, Agastya International, Naandi Foundation and several others. Occasional workshops with teacher educators have been conducted since 1998. Olympiad exposure camps for teachers have been conducted since 2010, in collaboration with teachers associations in Physics, Chemistry and Biology, which are described in Chapter 5. A number of visits of teachers and students are also hosted each year.

HBCSE’s teacher orientation workshops are very well regarded in the community and a growing number of requests for these are received each year. A special feature of these workshops is that they are hands-on and based on the continuous developmental work carried out in the labs, for example, the integrated lab and maths, D&T, Gnowledge and Olympiad labs. The workshop structure is often innovative and significantly informed by research. For example, teachers may be asked to administer a test or questionnaire to their students, the results of which are analyzed in the workshop. Research readings are discussed, student errors and alternative conceptions, classroom video excerpts and textbook approaches are analyzed by teachers, and sharing and reflection on practices is done. This approach to teacher education aims to develop ‘pedagogical content knowledge', building links between teacher education and the actual work of teaching, including reflection and learning from classroom experiences.

HBCSE's teacher education programs are therefore enriched by developmental work and also contribute to it; they are enriched by research in Science, Maths and Technology education, and also providing a context for it. This professionalism of our in-service teacher education had led to requests from national agencies to contribute also to course development, pre-service education and planning of large scale schemes for teachers. HBCSE members have worked on course development for pre-service teacher education for IGNOU, YCMOU and NIOS. Workshops have been conducted for teacher educators (i.e., faculty members of teacher education institutions) in Bihar and West Bengal, based on which material for teacher education is being developed. A faculty member of HBCSE is part of the National Council of Teacher Education, the apex body for regulation of teacher education in the country; another led a Joint Review Mission on teacher education in Punjab. As part of a nation-wide DST-MHRD initiative, in 2013 HBCSE prepared a detailed project report on "Building Educators for Science Teaching". Although DST did not take up the project, a year on in 2014, MHRD is adopting some of the ideas developed within it.

Teacher education at post-school levels is carried out through the Olympiad resource generation and exposure camps, and collaborations with teacher associations. These are described in Sections 5.4 and 5.7.

4.3 Future plans in teacher education

In the context of the increasing national recognition of the critical need for teacher education particularly in Science and Mathematics it has become urgent to review HBCSE's role in teacher education in the country, and to consider how best its expertise and resources could be used to achieve maximum impact in the field.

While the direct impact of HBCSE's programmes for teachers will be limited by the numbers for whom workshops can be conducted, the use of technology, as in the CUBE program, may provide some scaling up of such impact. In the country, print and electronic resources for teacher education are being sought at all levels, and are found to be lacking. National organizations like Eklavya and Azim Premji Foundation and international ones like TESS-India (Open University, funded by DFID) and World Bank are taking a lead in preparing such materials. It is an opportunity for HBCSE to bring its R&D strength to impact teacher education in the country. We have to decide whether to do this task independently or through strategic institutional collaborations and partnerships. HBCSE's earlier in-house curriculum development work, though rigorous and of high quality, has not automatically led to large-scale usage. This is an issue to reflect on as we plan future work in teacher education.

Another issue to address is that of continuity of programs and building of groups within HBCSE that can contribute to sustained developmental work. Association of our programs with ongoing pre-service courses may be one possibility. To some extent, the Mathematics education group and the Olympiad groups have maintained a continuity and enriched the repertory of resource materials over the years. These groups need to be strengthened and other groups, notably in school science, D&T and ICT need to be formed. Inter-group exchanges on new developments and methods are also lacking within HBCSE. These are essential not just in the area of teacher education but also overall, to strengthen R&D at HBCSE. The same methods that we advocate in teacher education, namely, collaboration, sharing of experiences and reflection on practices, need to be practised in the institutional context of HBCSE. This self-review document is one step in this direction.

Table 4.1: Early teacher education (1970s-90s)

S. No.	Project Name	Tier 1/2/3	Year Duration	Collaboratory Organizations	Subj: Science/Maths	Level Pri/Sec/Ter	Participants No.	Material Developed
1.	Khiroda Proj. (Rural Science Education)	1-tier	1975-78	Sane Guruji Vidya Prabhodhini, Khiroda, Dist.Jalgaon, Mah.	Science	Prim. & Upper Prim.	15 Prim.& middle schools	a) Teachers Handbks for Std.I-VII; b) Evaluation tool; c) Khiroda Conf.
2.	BMC Proj. (Dev. of Resource Centres)	1-tier	1974-83, 8y	Bombay Mun. Corpn	Science, Maths & English	Sec. Schools	50 teachers	a) Teachers Handbks for Std. VIII - IX; b) 5 Resource Centers.
3.	Joint Innovative Proj. (Satara Proj.)	1-tier	1985-88	SCERT & SISE, UNCEF funding	Science	Prim. & Upper Prim.	17 schools, Teachers & EOs	Kits of Apparatus
4.	Saturation Proj. (Chikhaldara/ Surgana)	2-tier	1987-90	Education Dept. & Tribal Dev. Dept	Science	Primary & Upper Primary	50 each	Sci exhibits (108) RPs evaluation tools
5.	Dahanu/Ramtek Proj.		1987-90	SCERT & SISE	Science & Maths	Secondary	116	Remedial Maths Book 1-4
6.	CLASS Project	1-tier	1984-90	Min. of Education, Govt. of India	Computer Literacy, Science & Maths	Secondary	50	10 Software packages on Maths, Stats & Chem.
7.	Solapur Proj.	2-tier	1990-93	Solapur Science Centre & Solapur Municipal Corpn	Science & Maths	Primary & Upper Prim. Secondary	700 tchrs, 95 Mun.Prim.Sch.; 70 tchrs, 15 sch.	Large scale expansion
8.	Ashram School Proj (Qual. Improvement) Ph.1 (Thane Regn)	1-tier	1993-96	Tribal Dev Dept, Thane	Science & Maths	Secondary	47 Ashram Schools	Samvad Magazine
9.	Rankol Proj (Activity Based Teaching Prog)	1-tier	1993-94	Gram mangal, Kosbad	Science	Primary	35	Low-cost Experiment
10.	Ashram School Proj, Phase 2 (Nashik Regn)	1-tier	1997-99	Tribal Dev. Dept, Nashik	Science & Maths	Secondary	90	Samvad Magazine

Chapter 5

Pre-university education (OLYMPIADS)

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The higher secondary or the so-called "plus-two" is a crucial stage of education in India. In cognizance of this, in 1994, HBCSE undertook the development of a full-fledged higher secondary wing along with setting up of training laboratories for development of experiments and demonstrations in Physics, Chemistry and Biology. The initial activities involved talent nurture programmes of selected students from all over India and orientation programmes for teachers (e.g., Atomic Energy Schools, Bharatiya Vidya Bhavan Schools).

5.1 Indian Olympiad programme: Background

The International Olympiads (IOs) present academic challenges of high difficulty level to young minds and thus represent celebration of the best in senior secondary and pre-university sciences. In 1997, the then Secretary of the Department of Atomic Energy (DAE) suggested to the Indian Association of Physics Teachers (IAPT) and HBCSE to jointly prepare a proposal to conduct a Physics Olympiad programme in India that would lead to Indian participation in the International Physics Olympiad. The DAE agreed to support the Physics Olympiad programme. By this time, advanced laboratories at HBCSE were also ready with a number of innovative experiments and demonstrations to conduct the training of students and teachers. Thus the Olympiad activity began at HBCSE in October 1997 with a selection and training camp in Physics for about 20 students.

The Olympiad activity was a natural fall-out of the Homi Bhabha Study Circle, a regular weekly programme of problem-solving and critical discussions conducted for undergraduate Physics students. The Study Circle started in 1984 had, over the years, stimulated development of co-curricular material in physics for the higher secondary and introductory college levels. A total of 1200 innovative exercises for plus-two level in Physics were designed (which were subsequently included in relevant NCERT textbooks) and three books of an interrogative series “How and Why in Physics” were brought out. This material has been useful for the Physics Olympiad programme and several plus-two teacher orientation courses held across the country.

In 1998, HBCSE in collaboration with IAPT conducted the first Indian National Physics Olympiad (INPhO) for about 200 students at 12 centers across the country. Unlike many other similar competitions which had only the theory component, INPhO had an equally important experimental component. Two experimental problems and 200 copies of required experimental setups were developed for INPhO 1998. In summer 1998, a four week training camp was organised at HBCSE for about 30 students. The first ever Indian team for International Physics Olympiad (IPhO) was selected during this camp. After another round of pre-departure training, the Indian team participated in the IPhO 1998 held in Iceland.

India has been participating in the International Mathematical Olympiad (IMO) since 1989 (HBCSE took over the co-ordination in 1997, on the request of the National Board of Higher Mathematics (NBHM)). HBCSE spearheaded India’s entry into the different Science Olympiads (Physics in 1998, Chemistry and Astronomy in 1999, Biology in 2000, and Junior Science in 2004). Good performance of the Indian teams right from their entry acted as a catalyst and led to the consolidation of the national Olympiad programme. Availability of country-wide network of Indian Association of Physics Teachers (IAPT) helped in smooth launching of the Science Olympiad programme in the country. Involvement of teacher associations and various decisive funding departments such as the Department of Atomic Energy (DAE), Department of Science and Technology (DST), Ministry of Human Resource Development (MHRD) and Department of Space on a consensual basis is the key factor that triggered the inception and growth of the programme.

5.2 Current status

The Olympiad programme is a highly time-bound activity that runs throughout the year. From its inception, the programme has undergone several changes with respect to the academic and administrative aspects. The current selection of Indian teams involves three stages. The procedure is identical for all the science subjects and is slightly different for mathematics, which is described separately below.

5.3 Three-stage selection process and training

The academic responsibility of the first stage in the science subjects lies with respective teacher organisations (namely, Indian Association of Physics Teachers (IAPT), Association of Chemistry Teachers (ACT) and Association of Teachers in Biological Sciences (ATBS)) whereas the administrative responsibility is handled solely by IAPT. The first level examination (called National Standard Examinations - NSEs), conducted at around 900 centres across India (in November) is taken by students at both Class XI and XII level. The Junior Science Olympiad and the junior level of the Astronomy Olympiad are taken by students between classes VIII and X. It contains objective-type questions.

The second stage (called Indian National Examinations: INOs) is conducted at around 16 different centres in late January or early February. It consists of objective as well as descriptive problems of high difficulty level designed on the lines of those appearing at the International Olympiads. The academic as well as administrative responsibility from the second stage onwards lies completely with HBCSE. A strong academic involvement of high school and college teachers in respective subjects is present in the resource generation and training of students at the later stages.

While the participation in the first test runs into tens of thousands (for example, the enrolment in the year 2012-13 was about 41000 in Physics, 35000 in Chemistry, 14000 in Biology, 12000 in Astronomy and 25000 in Junior science), the second level is limited to the top 300 students in each subject.

In the final selection, about 40 students in each subject are selected from the Indian National Olympiad examinations and are invited for Orientation-cum-Selection Camps (OCSCs) held at HBCSE. During these camps, which last between two weeks and a month, students appear for several theoretical and experimental tests, leading to the selection of Indian teams for the final International Olympiads. Over 200 of the best students from across the nation are exposed to a high level experimental and theoretical training every year at the OCSCs. The teams (consisting of 4 to 6 students, depending on the stream) are selected at the end of the OCSCs and are trained for about two weeks just prior to their participation at the international events at the Pre-Departure Training camps at HBCSE (IO-PDTs).

A similar pattern of selection and training is followed by HBCSE for Mathematics under the aegis of the National Board of Higher Mathematics (NBHM). The first stage consists of the Regional Mathematical Olympiad (RMO) and is taken by a large number of students (around 30000 in 2012-13). Both the academic and administrative responsibilities of RMO are shared by HBCSE and regional coordinators appointed by NBHM. The second stage, called the Indian National Mathematical Olympiad (INMO), is organised by HBCSE and is limited to the top 750 students from RMO. Both stages have subjective type questions. About 60 students selected through INMO held in the current year and the previous year are invited to attend a month-long training camp at HBCSE, called the International Mathematical Olympiad Training Camp (IMOTC). A six-member team for the international competition is selected through four tests held during IMOTC. Further training is imparted to the team for a ten-day period prior to their departure for the International Olympiad.

The special Olympiad laboratories in Astronomy, Biology, Chemistry, Junior Science and Physics at HBCSE design, develop and standardise new experiments on continual

Table 5.1: Performance of Indian teams at international Olympiads (since 2000)

Subject	Years	Gold	Silver	Bronze	Hon. Mention
Physics	2000-2013	29	26	11	4
Chemistry	2000-2013	16	28	12	—
Biology	2000-2013	7	36	13	—
Astronomy (IAO)	2000-2013	41	20	8	—
Astronomy (IOAA)	2008-2013	13	10	7	—
Maths	2000-2014	6	34	30	18
Junior Science	2008-2013	16	28	1	—

Table 5.2: International Olympiads hosted (and planned) by India

No.	Year	Subject	Participating Countries
1.	1996	Mathematics	
2.	2001	Chemistry	54
3.	2006	Astronomy	19
4.	2008	Biology	55
5.	2012	Asian Physics Olympiad	
6.	2013	Junior Science	43
7.	2015	Physics	—
8.	2017	Astronomy & Astrophysics	–

basis and these experiments are valuable inputs for the higher secondary and undergraduate science laboratories in the country.

Every year, the Olympiad programme sends 30 students to represent India in the International Olympiads in Physics, Chemistry, Biology, Mathematics, Astronomy and Junior Science. It is worth mentioning that till date almost all participants have won medals including numerous gold medals (see Table 5.1 and Table 5.2). For the year 2012, 29 out of 30 won medals and this included 11 coveted gold medals. Based on aggregate scores, India is generally among the top ten nations in the Astronomy, Biology, Chemistry, Junior Science, and Physics Olympiads (For details refer to Table 5.1, Table 5.2 and the series of tables in Appendix F.

It might be noted that apart from the six Olympiads directly under its supervision, HBCSE contributes substantially in the selection and training of students for the International Astronomy Olympiad (since 2010) and the Asian Physics Olympiad (since 2000).

5.4 Resource generation and outreach

From year 2004, as a part of the Olympiad programme, HBCSE has been hosting "Resource Generation Camps" (RGCs, at the centre and out of station) in which invited teachers and scientists interact with HBCSE personnel to discuss and devise new problems and experiments. These discussions provide valuable exposure to college teachers at state of the art laboratories and challenging theoretical questions. At the same time, scientists and researchers get familiarised with real problems affecting college level science education in the country. From year 2009, HBCSE introduced "Olympiad Exposure Camps" particularly for teachers teaching science at higher secondary level which introduce the Olympiad programme and its academic challenges to the teachers. These camps often involve discussions regarding the content and pedagogical aspects of the subject and help to alleviate common misconceptions about subtle points among teachers, and thereby, future students. More than thousand teachers have so far attended resource generation and exposure camps, some even from Bangladesh, Sri Lanka, Nepal and Thailand. Apart from these camps, HBCSE personnel have been regularly visiting different parts of the country (especially non-metropolitan regions) to deliver talks and run training camps for teachers and students.

5.5 Publications

HBCSE staff members have published several books containing problems from national and international Olympiad examinations, accompanied by detailed solutions of the same. These books have a wide circulation, generating lot of enthusiasm among students for the Olympiads and repeated reprints have been fully sold out. Apart from these books, a few papers have been published in national journals like Resonance and Physics Education describing the Olympiad movement in India. Some pedagogical and research articles have also been written on Olympiad problems and experiments in peer reviewed journals (E.g. (Vartak, Ronad, & Ghanekar, 2013)). The publications are summarised In Table 5.3 and listed in detail in a booklet (Mazumdar, 2014).

Table 5.3: Summary of Olympiad publications

Overview articles	Books	Articles in journals	Short articles in bulletins
3	14	39	82

Details of Olympiad publications are given in a separate booklet (Mazumdar, 2014).

5.6 Critical appraisal and future direction

It is due to the dedication and hard work of a core group of resource personnel, both from inside HBCSE and outside, that the Olympiad programme has continued to run smoothly over more than a decade. The contributions of the science teacher associations, IAPT, ACT and ATBS, and in mathematics, NBHM, must also be recognised in this respect.

Since the culmination of the programme is an international competition, the national programme must be designed to act as a sieve for selecting the best students in the country in each subject. Thus, the focus of the programme is on encouraging and nurturing talent at the high school level and not on remedial measures for a vast student population. In particular, the tight schedule guided by the time-line of the international competition does not allow either for an extended teaching opportunity or a great deal of outreach activities.

Despite these restrictions, the Olympiad programme could and should have a component which transcends the competitive aspect to encompass a broader population of students outside the extremely meritorious few who make it through the selection process. This aspect of Olympiads is recognised by HBCSE and several measures have been taken over the years to reach this goal.

5.7 Teacher support

HBCSE has overseen the formation of teacher associations in Chemistry (ACT) and Biology (ATBS), and continues to nurture them. It has also developed a very strong collaboration with the already existing association for Physics teachers (IAPT) and the Bombay Association of Science Education (BASE). All these teacher organisations have been afforded office space in the HBCSE campus. Through the synergistic collaboration with these voluntary teacher organisations, HBCSE is able to a) spread the message of Olympiads, and later NIUS, among a vast population of teachers and students across the country, b) actively involve teachers as resource personnel in the academic exercise of the Olympiad programme, and c) take their help in organising the preliminary tests in every corner of the country. Thus, such cooperation between a central institute for science education like HBCSE and national teacher organisations is desirable, and must be strengthened further.

Numerous exposure camps and resource generation camps conducted by HBCSE help

(a) to involve grassroot level teachers in the Olympiad programme,

(b) to bring the academic challenges of the Olympiads to the doorsteps of students across the country through their teachers,

(c) teachers to look at their subjects in novel and refreshing ways, especially in terms of conceptual and procedural understanding,

(d) in generating a resource pool of teachers who are involved in training teachers and students in future camps (multiplicative effect) and

(e) to expose students and teachers to the experimental facilities that are uniquely different and advanced compared to what they encounter in their regular tenures in schools and colleges.

However, still the number of teachers who are competent enough to train students at the higher level required for Olympiads is very small. This lacuna can be addressed by teacher training programmes, specifically focussed on the Olympiads. This is a very difficult task given the existing high workload on secondary and higher secondary school teachers, on the one hand, and the paucity of teacher educators at this level, on the other.

5.8 Broadening the pedagogical benefits

The books published by HBCSE on Olympiad problems aim to disseminate quality material developed in the course of the Olympiad programme among a large population of students, a goal which has at least partially been met. Several books on problem-solving techniques for the Olympiads have also been written by authors outside HBCSE, especially in Mathematics.

Members of HBCSE Olympiad cells have been regularly serving on science textbook writing committees for NCERT at the secondary and higher secondary levels. These books are adopted as the standard textbooks by CBSE as well as many of the state-level educational boards. Many of the conceptual problems developed in the course of the Olympiad programme have found their way into these books as exemplar problems, thereby encouraging students at large to take up the challenge of excellence at the school level.

The Olympiad programme complements several other higher level assessment and talent nurture programmes in the country such as the Proficiency Test conducted by the Central Board of Secondary Education (CBSE), National Talent Search Scheme (NTSS) by National Council for Educational Research and Training (NCERT), the Kishore Vaigyanik Protsahan Yojana (KVPY) of Department of Science and Technology (DST) implemented by Indian Institute of Science (IISc, Bengaluru), and the INSPIRE programme (DST). Members of the Olympiad cells at HBCSE are heavily involved in each of these programmes, thus providing an efficient channel for the exchange of expertise in higher level assessment and talent nurture.

5.9 Emphasis on experimental science

One of the unique aspects of the Olympiad programme is its significant emphasis on experimental science. Most talent nurture programmes or competitive examinations in the country focus purely on theoretical aspects of a subject, thereby creating a learning environment in which the student is hardly encouraged to hone his/her experimental skills. By exposing students to innovative and novel experiments and training them in the methods of experimental science, the Olympiad programme helps to correct this imbalance to some degree. There is an acute need of motivated bright students in research laboratories across the country and the Olympiad programme should help to open this vista for the students at an early stage. The Olympiad laboratories at HBCSE are equipped to the level of international standards, much beyond the typical facilities found in Indian schools and colleges. Several experimental kits developed at HBCSE have been distributed to a number of schools across India and also through the IAPT network. This aspect of the programme must be preserved and efficient ways of disseminating pedagogic material relevant to experimental science need to be found.

5.10 Motivating students and continued nurture

The success of the Olympiad programme can in some measure be estimated by the long-term effect it has on students participating in it. It has been observed that a large fraction of the students who go through the Olympiad experience continue their academic pursuits in the future. Many of these students take up professional courses immediately beyond the higher secondary stage, but more often than not they continue their careers through doctoral research in respective domains. Some of them even return to the pursuit of basic sciences and mathematics.

Data on careers pursued by the olympiad students is available for those who have attended the astronomy OCSCs during 1999 to 2013. Over these 15 years, we have sent a total of 68 students for 99 participations in the IAO and IOAA (see Figure 5.1). As of March 2013, out of these 68 students, 7 were still in high school (K-12 coloured brown) and 27 in undergraduate classes (light blue). Of these, 13 students were in undergraduate engineering, 3 more in undergraduate engineering but were committed to a career in astronomy, 8 were pursuing a degree in physics and another 3 were in other branches of pure science. Twenty students (yellow) are pursing research and Ph.D.: 2 in astronomy, 4 in physics, 6 in other physical sciences such as mathematics and neuro-science and 8 in engineering. Nine students (light green) are in industry, 6 as corporate executives in varying sectors and 3 in industrial research and development. We are not in touch with 5 students, who all have graduated from various technical institutes.

While it is difficult to prove a direct connection between their involvement in the Olympiad programme and their future retention in academics, informal feedback from many students indicates that they are indeed highly motivated to continue in science or mathematics as a result of the Olympiad experience. In fact, the NIUS programme (described later) was born out of the need to nurture talented students in the Olympiad programme further during their undergraduate careers. In astronomy nurture camps are held every year for past olympiad students.

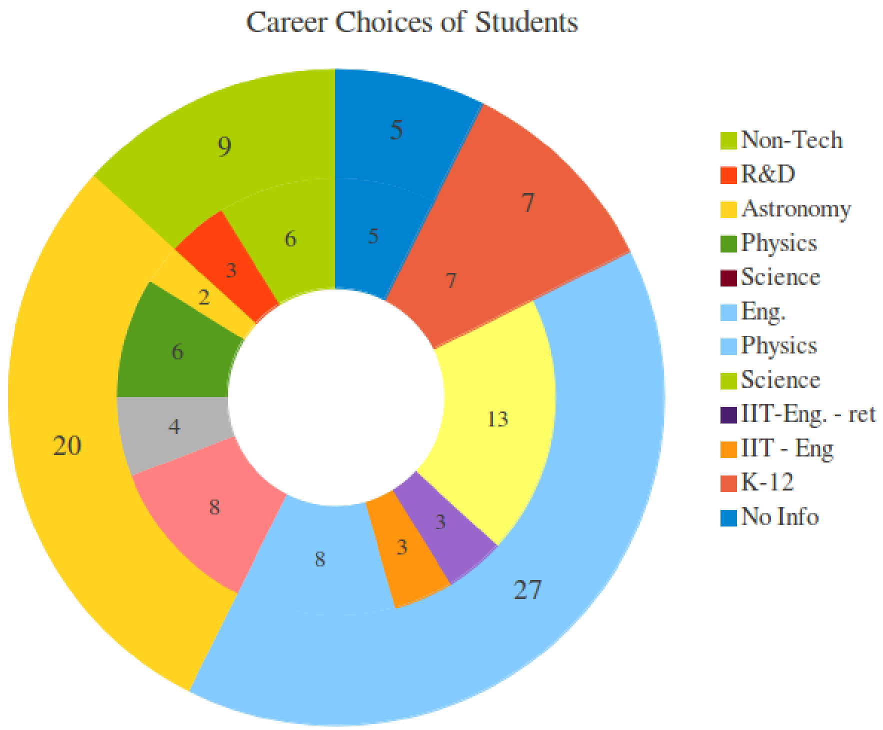

Figure 5.1: Career choices of students attending OCSCs for IAO and IOAA during 1999-2013

5.11 Organisational responsibility

Currently, the Science Olympiads and, to a lesser extent, the Mathematical Olympiad are largely run from the central node at HBCSE. This puts an immense strain on the limited resources of HBCSE, more so in terms of human effort rather than financial burden. For the programme to prosper in the long run and spread to an even greater population of students, particularly in non-metropolitan areas, a degree of decentralisation will perhaps be helpful. One could conceivably have regional centres set up which can have certain autonomy in conducting local Olympiads. However, this model is fraught with the risk of creating a disparity in the rigour level of the programme across different regions which might not be desirable. Another option is to have the preliminary level divested to local educational organisations, while retaining the final selection and training with HBCSE. This is somewhat along the lines of the Mathematical Olympiad where the RMO is largely the responsibility of the local centres. It must be borne in mind though that even for the RMO, the entire exercise is carried out under the watchful eyes of the NBHM and the academic input is still largely from HBCSE. Further, the voluntary involvement of the teacher organisations is crucial in the programme in terms of the propagation of the Olympiad movement across the nation. It is hard to find reliable agencies with a commitment comparable to that of the teacher organisations, and it might not be prudent to lose the opportunity to reach out to a large number of students through their mentors, namely the teachers. Therefore, any reorganisation of the Olympiad programme must take into consideration the questions of uniformity and fairness in the selection process, as well as the importance of having a central node for the academic endeavour so that efforts are neither duplicated, nor is valuable experience gained through the years lost.

5.12 Human resources requirement

The major constraint for the Olympiad programme is an acute shortage of staff. Currently, one academic member, two scientific members with the help of three to four temporary staff members shoulder the responsibility of running the Olympiad activity in each of Physics, Chemistry and Biology. The Mathematical Olympiad cell currently does not have any scientific staff associated with the programme whereas for Astronomy and Junior Science Olympiads only one scientific staff along with the academic member is involved with the programme. Further, in Physics, Chemistry, Biology and Astronomy, the same groups of personnel are responsible for running another major programme at the undergraduate level, namely, the National Initiative on Undergraduate Sciences (NIUS). It must be borne in mind that both these programmes require elaborate preparation, both in terms of theoretical work, and in particular, experimental design and testing. The recent development of new laboratory infrastructure has eased the situation somewhat as compared to that existing at the inception of the Olympiad programme. Nevertheless, this puts an enormous workload on the limited number of staff members throughout the year and restricts the scope of both the Olympiad and the NIUS programmes. While a broader initiative for the Olympiads might be desirable, it is practically impossible to implement any expansion with the current staff strength.

A major overhead of the Olympiad programme is the administrative task. There is a huge logistical planning to be made every year for conducting the INO/INMO, the OCSC/IMOTC, the PDC and the final international trip to the Olympiads. This includes all the formalities of the examination procedure, accommodation, boarding and medical arrangements, travel and visa arrangements and a major financial bookkeeping. Except for the accounting, which is managed by the HBCSE central Accounts section, all the other tasks are handled by the respective cells and the office of the National Coordinator of Science Olympiads. However, the cells have no administrative staff assigned to them and the NC office has only one permanent officer. Not surprisingly, therefore, a large part of the administrative burden falls on the shoulders of the academic and scientific staff in each cell. This consumes a significant part of the working time of these members, a time which should ideally be spent in academic pursuits. Also, the poor strength of the centralised NC office means many mundane tasks are duplicated across the cells, which could well have been managed in a more efficient way by a common office with higher capacity.

5.13 Summary

The Olympiad programme in the sciences and mathematics has now run for fifteen years at HBCSE. It has identified and trained bright young minds from all over the country that have subsequently represented India at the highest academic level suitable for the age. The students who have participated at the international Olympiad competitions over the years have, almost without fail, returned with a medal or at the least, an honourable mention. Thus, it would not be an overstatement to say that this has been a largely successful and vigorous programme.

The primary credit for this success obviously lies with the students themselves. However, no talent can thrive without careful nurturing and no skill can find perfection without honing. It is in this regard that HBCSE makes its contribution. The regular long-term instruction and training of the students obviously happens at their schools, and perhaps at home and other institutions. But the rigorous training at HBCSE, albeit over a short period, helps the students to make the giant leap between regular curriculum-based training and the higher strata of international Olympiads. It provides the extra fillip needed to compete and thrive at the challenging fora of the Olympiads. This is especially true for the experimental aspect, where the facilities provided by HBCSE and the novel designs of experiments make a significant difference to the students' skills in this area. It seems obvious that this programme should be continued at HBCSE. However, like any programme, it has to adjust to the changing context of Indian educational scenario.

The whole process of setting questions and developing experiments for different selection rounds of the Olympiad programme has enhanced the content expertise of the members involved. By designing conceptual and challenging problems, developing novel experiments, actively participating in book writing for Olympiads, being part of educational bodies at the national and state levels, and serving on national level assessment committees, the cell members of the Olympiad programme have provided a benchmark for quality education at the Higher Secondary and Undergraduate level in the country. Several Olympiad related pedagogical articles have been published and more such efforts are needed for further propagation of pedagogical benefits of the programme.

5.14 Future plans - Olympiads

5.14.1 Further growth and consolidation

In the coming years, the Olympiad programme needs to increase its reach in different parts of the country. The programme has so far not penetrated much into the rural areas of the country. Most of the students that participate are from urban and semi-urban locations. This is not due to any inherent weakness in the rural students, but is mainly because of lack of awareness about the programme among them and their teachers. As a consequence, they are not exposed to Olympiad-type problems at all during their schooling and it perhaps becomes more difficult for them to compete. This is not an easy problem to solve given the scale of the nation. However, some steps must be taken to disseminate information about the Olympiads in rural areas.

The possible ways for enhancing the reach of the programme are a) to network with teachers at the grassroot level though local chapter of teachers associations b) by establishing Olympiad centres at regional level, c) by increasing number of RGCs and ECs and holding them at different parts of the country in collaboration with teacher associations.

One also needs to disseminate both information and academic content pertaining to the Olympiads directly among the student community at large. This may be efficiently done through electronic media, supplemented by printed material and efforts in this direction are in progress. Collaboration with country-wide institutions like the Kendriya Vidyalayas or national talent-nurture programmes such as INSPIRE and KVPY may be explored too.

While working in these direction, it is also important that one does not lose touch with the ground realities of education in the country. Decentralisation of the preliminary levels may be an option, but that needs to be carefully planned and executed.

A system of tracking the future career paths of Olympiad students, the percentage male and females in students who appear for INOs (variation in this percentage over years and across subjects), career paths taken by top 40 students who attend the OCSC etc. needs to be put in place at HBCSE.

5.14.2 Human resource requirement

The major requirement for further augmentation of the Olympiad programme is human resources. Optimal requirement for human resources across different categories for the Olympiad is indicated below.

A significant portion of the workload, especially in the laboratories, is carried currently by temporary personnel like Project Assistants and Project Fellows. The drawback of this model is that such staff cannot be retained beyond three years, and therefore, no long-term expertise can be built. By the time they learn the methods of operation and start contributing independently, it is time for them to leave, and the whole cycle has to start again. Therefore, we have proposed to hire Scientific Assistants or Laboratory Assistants in each cell. The acute shortage of administrative staff needs to be rectified at the earliest by setting up an office with at least two administrative officers and two assistants.

Chapter 6

Undergraduate education

6.1 National Initiative on Undergraduate Science (NIUS)

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The National Initiative on Undergraduate Science (NIUS) was launched in the summer of 2004 as a sequel to the Olympiad programme (NIUS Proposal, 2004). This programme has further extended HBCSE activity profile to tertiary level education.

6.1.1 Background

It was motivated by two key issues concerning tertiary science education in India, namely, a) declining number of meritorious students for B.Sc./M.Sc. courses, and b) lack of academic excitement and motivation in B.Sc. programmes. The end result is that most students, including those with considerable talent, go through it without any serious motivation and by the time they complete their degree programmes, most of them lose interest in pursuing research careers.

Two more important observations catalysed the conceptualization of NIUS. (a) The undergraduate science colleges in India do have a small (as a fraction) but significant (in terms of absolute numbers) population of good and motivated students who aspire to do well in basic science careers, even though they had an option to go for professional degrees. b) Through interactions with Olympiad students, HBCSE observed many of these meritorious students had genuine interest in pursuing studies in basic sciences or mathematics, even though they may have made the 'pragmatic' choice of going in for professional degrees. Experience over the last several years shows that several

[1]Overlapping with Chapter 5

of such bright students look for opportunities to learn basic sciences through special enrichment programmes wherever they can find them.

When the NIUS was being initiated by HBCSE, the need for undergraduate nurture programmes was appreciated in the country so as to attract good undergraduate students to sciences, to secure the future of science in India. Several leading institutions in the country (IISc, RRI, SINP, TIFR, JNCASR, to name a few) had already taken steps to avert the problem and started offering short programmes such as summer research projects to motivate bright young students (mostly at the M.Sc. level) to research careers in sciences. In mathematics, NBHM had been successfully coordinating nurture programmes in mathematics for many years. However, these programmes were limited in scope both in terms of the number of students that they could cover and the duration of time over which they would involve students. As a result, large number of students at the undergraduate level were left without any exposure to research, which could possibly serve as a great motivating factor in their continued engagement in the pursuit of science.

NIUS was conceived to be a large scale, comprehensive and sustained programme, encompassing all basic sciences. It was envisaged as a strong programme for the nurture of undergraduate science students with special emphasis on research, especially experimental research and instrumentation development. At the same time, it was to have other components like collaboration between scientists and college teachers and development of undergraduate teaching tools. In short, NIUS was designed to be a major new national initiative on undergraduate science that focuses on early and sustained nurture of potential Indian scientists of the future.

6.1.2 Current activities

As stated above, the main thrust of the programme is to promote undergraduate research. Development of theoretical and laboratory courses, preparation of lecture notes, research and development in science education and training of students and teachers in experimental science are other equally important aspects of NIUS programme. Another facet of the programme has been to assist college teachers in setting up modest research programs at their own institutions which can further help in mentoring undergraduate students at local levels. The administrative responsibilities of the programme involve coordination with scientists and students, organizing nurture camps and purchase of equipments, etc.

6.1.3 Undergraduate research programme

NIUS research fellowships

Since 2004, this has been the flagship programme of NIUS. The aim is to provide a taste of research to students during their undergraduate stints, thereby motivating them to academic excellence and demonstrating the option of being a scientific researcher to be a viable career path.

At present this programme runs in the three streams of biology, chemistry and physics, including astronomy. The model on which it works is broadly the same in all streams and is as follows. Students are first invited to a two-week exposure and enrichment camp at HBCSE during or at the end of their first year undergraduate courses in science or engineering. Experts from different institutions including HBCSE lecture on areas of frontline research during this camp. The topics are chosen carefully so as to be amenable at the undergraduate level and the lectures are pedagogical in nature, delivered in sets of three or four in a classroom teaching mode, rather than as seminars. At the end of this first camp, students are assigned to do research projects over the next couple of years under the mentorship of scientists in different research institutions. The mentors are usually, but not limited to, the lecturers at the first camp. The number of students who are given the opportunity of doing a project is limited by the number of available mentors, and is between 60% to 80% of the number of participants of the first camp (see Table 6.1). After the mentors are assigned, the students would visit their respective mentors at their places of work several times during the next two years to carry out the projects. These visits usually last two to four weeks during summer and winter holiday periods of the students, and are typically three to four times over the duration of the project. At the end of two years the students are required to submit a report of their project, and sometimes to present their work in an open seminar. Some of the project work carried out by students are of sufficiently high standard and are published in international journals. Approximately one-third of the enrolled students successfully complete their projects. It may however be noted that first camp itself provides guidance enrichment and tremendous motivation to the students.

Table 6.1: Annual student intake in NIUS programme.

S.No.	Batches	Year	Students enrolled		
			Physics	Chemistry	Biology
1	I	2004-2005	27	31	29
2	II	2005-2006	40	18	15
3	III	2006-2007	35	7	10
4	IV	2007-2008	43	25	14
5	V	2008-2009	49	14	12
6	VI	2009-2010	51	39	7
7	VII	2010-2011	67	40	20
8	VIII	2011-2012	73	44	29
9	IX	2012-2013	69	53	38
10	X	2013-2014	62	44	27
Total number of of students			516	315	201

Till date around 1000 undergraduate students have been exposed to this programme under the aegis of the exposure-cum-enrichment camps. The detailed year- and subject-

Table 6.2: Summary of activities (2004-2013) under NIUS programme.

1.	Exposure and enrichment camps for students	96
2.	Lecture notes prepared	15
3.	No. of completed projects	98

Note: For details see http://nius.hbcse.tifr.res.in/

Table 6.3: Summary of NIUS publications

Overview articles	Books and technical reports	Articles in journals	Articles in conference proceedings	Presentations in conferences
2	5	81	31	23

Details of NIUS publications are given in a separate booklet (Mazumdar, 2014).

wise numbers are given in Table 6.1. About 100 projects have been completed so far while another 80 are in progress currently. In all, there have been over 100 publications resulting from NIUS student projects in international journals and conference proceedings. The summary of NIUS activities is given in Table 6.2, the kinds of publications are summarised in Table 6.3. The publications are listed in a separate booklet (Mazumdar, 2014). About 15 pedagogical lecture notes have been written up and edited, and will assist in curriculum development at the undergraduate level. Some of these have already been widely disseminated and constitute valuable resource material.

In Biology the following areas are covered: Cell Biology, Microbiology, Biochemistry, Bioinformatics and Molecular Biology. Resource persons are drawn from HBCSE, IIT Mumbai, Pune University, TDM Lab (Mumbai), M. S. University (Baroda), UM-DAE CBS (Mumbai), Visva-Bharati (Santiniketan), Calcutta University (Kolkata) and many local colleges under Mumbai University.

In Chemistry, the following areas are covered: Computational Chemistry, Organic Chemistry (Green synthesis routes and Physical Organic Chemistry), Interfacial Chemistry, Catalysis and material chemistry (including nonmaterials) Resource persons are drawn from HBCSE, IIT (Mumbai) , ICT (Mumbai), TIFR, BARC, IISER (Pune), local colleges of Mumbai University and Chemical industries (The BASF, Cipla, and Tata Chemicals).

In Physics, the following areas are covered: Quantum Computing, Astrophysics, Neutrino physics, physics of Semiconductor Nanostructures, Instrumentation and optical measurements, and the application of techniques of Statistical Mechanics to cognitive science and science education. Resource persons are drawn from HBCSE, TIFR, BARC, IISERs, NCRA, IUCAA, RRI, as well as from a number of colleges in the non-metropolitan areas of the nation.

Promoting undergraduate research in non-metropolitan colleges

Apart from the main programme of undergraduate research through the NIUS camps, it is also planned to seed research initiatives by college teachers in their respective places of work. The task of identifying, encouraging and working with faculty in non-metropolitan colleges has been initiated. This has been done in half a dozen places in India notably in Christ Church college, Kanpur (Kanpur University), Science College, Patna (Patna University), Jagdam College, Chapra, (Jaiprakash Narayan University), B.S.College, Danapur (Magadh university), DAV PG College, Rishikesh (Tehri Garhwal University), Physics Dept., H.S Gour university, Sagar, MP and Sharana Basaveshwara College of Science, Gulbarga University. Our perspective is to enable the teachers to set up a modest research effort so that they in turn will mentor the undergraduate students. In the places mentioned above the plan has been put in place and is operative. The research areas are nanophysics (both theoretical and experimental) and quantum chaos.

Nurture camp in astronomy

A two-week camp is held in December every year for students interested in astronomy and astrophysics. About 20 undergraduate students carry out short projects on topics in astronomy under the guidance of mentors in neighbouring institutions like TIFR and NCRA. At the end of the camp they give short presentations of their work, which are evaluated by an expert committee. The aim is to generate interest in the subject of astronomy which is not included in the undergraduate curriculum usually.

6.1.4 Educational initiatives in experimental physics

Apart from the research initiative, NIUS has also forayed into laboratory development and courses in experimental science.

Summer course in Experimental Physics

A two-week summer course in experimental physics is being conducted since 2012. It is designed as an enrichment course and is based on “Experimental Problem Solving” approach for undergraduate students and teachers. This approach is designed at HBCSE, to encourage students’ independent thinking in physics laboratory and foster Procedural Understanding in students. In this approach, we encourage students’ active participation, and independent thinking. During this course students are mentored by a team of invited teachers and encouraged to carry out independent work on a set of ‘experimental problems’ in Physics.

The objectives of this course are a) building up students’ motivation towards experimental physics and familiarizing them with innovative experimental activities/problems and demonstrations in physics, b) developing an integrated view of theory and experiments c) strengthening conceptual understanding, procedural understanding, experimental problem solving ability and experimental skills and d) offering students an experience of working in a "free" physics training laboratory.

NIUS (Physics) project in instrumentation

In the year 2009, a project on the "Development of Instruments and Experimental setups for the Undergraduate Physics Teaching Laboratories" was proposed and initiated at HBCSE. The project involved the development of low cost instruments for the measurement of various physical quantities, novel versions of the existing apparatus, experiments/ experimental setups, and low cost computer interfaced experimental setups. In this project, a number of students were involved and contributed to the developmental work. During the first few years, a basic instrumentation laboratory facility was developed. In spite of an unsuccessful effort of collaboration and MOU with WRIC, Mumbai and IUAC New Delhi, the developmental work was initiated, at a smaller scale, at HBCSE. During the past three years, about 7 complete experimental setups, 6 novel measuring/laboratory instruments, which include digital timer units, velocity measurement unit, mechanical simple harmonic vibrator, Fourier analysis, electromagnetic damping system etc. were designed and developed at HBCSE.

HBCSE-CMI course in experimental physics (2004-2009)

Under the NIUS (Physics) programme, during 2004 and 2009, Every year, HBCSE organized four week course in experimental physics for the first year B. Sc. Physics students from Chennai Mathematical Institute (CMI), Chennai during the month of May-June. HBCSE took the complete responsibility of planning and conducting the course, which included, formulating the content of the course, designing of experimental problems, preparing the students handouts etc.

Development of physics lab course and related material

From the year 2006, NIUS expanded its scope of developmental work with the establishment of and association with IISER-Pune, NISER-Bhubaneswar and UM-DAE-CBS-Mumbai.

1. HBCSE developed the FIRST semester physics laboratory course (PL 101) for the five-year MS programme launched at NISER, Bhubaneshwar and UM-DAE-CBS, Mumbai. The course was based on 10 innovative experimental problems. A suitable instructional strategy based on the 'guided problem solving' for the laboratory course was developed and implemented. HBCSE took the complete responsibility of the development and even the experimental set-ups were first designed / procured at HBCSE and then transported to the respective places.

2. HBCSE contributed during the initial stages of development of Physics laboratory course (PL 101, Mechanics) for IISER, Pune.

3. HBCSE developed the third semester physics laboratory course (PL 301) for the five-year MS programme at UM-DAE-CBS, Mumbai. The course was based on 14 experimental problems and a set of demonstrations. The emphasis of the course was to develop various advanced level abilities related to experimental physics, procedural, and conceptual understanding.

NIUS workshops for undergraduate teachers

One important activity of NIUS is holding teacher workshops. These workshops are planned to be of two types: one on classroom topics, and the other on advanced areas of research. The first type aims to develop better pedagogical tools for teaching standard curriculum material as well as topics which may not yet be included in the curriculum but are accessible at the undergraduate level. The second type would motivate teachers to engage in research themselves, and in the process provide exposure and opportunities for students also. Several NIUS workshops have been conducted in the areas of statistical physics, nanoscience and classroom demonstrations. The aim of these workshops were i) to orient these college teachers towards statistical mechanics, an area not touched upon in undergraduate physics: ii) to assist in the preparation of the pedagogical lecture notes introducing undergraduate students and college teachers to the physics of second order phase transitions; iii) development of interesting experiments for undergraduate physics laboratory. Over 100 participants, mainly from non-metropolitan areas across the nation, have have attended these workshops. Forthcoming workshops include one on basic computational science.

6.1.5 Contribution at newly established science education institutes

NIUS greatly expanded its scope of work with the establishment of Department of Atomic Energy (DAE) aided institutions: National Institute of Science Education and Research (NISER), Bhubhaneshwar and University of Mumbai-Department of Atomic Energy for excellence in Basics Science (UM-DAE CBS). As part of NIUS, HBCSE was proactively involved in the initial curriculum designs of these institutes as well as IISER Pune and development of its first year laboratories in all the three subject. Contributions in physics have been noted above. The entire experimental setup was first assembled at HBCSE and then transferred to NISER and CBS. In chemistry, the first year laboratory activity of CBS students in 2008-2009 and 2009-2010 was carried out entirely at HBCSE. Besides, NIUS members were also actively involved in carrying out the first year physics teaching programme of CBS, Mumbai. HBCSE also conducted National Entrance Screening Test (NEST 2007) for these institutes, and its members played an active role in the subsequent interviews for admission to them.

6.1.6 Science education research

Science Education Research has been carried out as part of NIUS since its inception. Early efforts were directed towards devising improved techniques for evaluation. This led to a novel parameterization scheme for distractors in item response analysis as well as a proposal for an entropy based index. Models from statistical mechanics were employed to model the teaching learning process. Undergraduate students were involved in this effort.

More recently a major effort has been devoted towards the development of concept inventories in rotational mechanics (see Section 2.3.2). A concept inventory is a set of carefully crafted multiple choice questions aimed at probing misconceptions, deficient understanding and eliciting ill suited reasoning patterns. The concept inventory on rotational kinematics, which has been developed here has been widely tested both here and in the USA. The data analysis uncovered interesting misconceptions and pitfalls in reasoning. High ability students, students from semi-urban areas and teachers have benefited from this effort. The results were presented in international conferences and published in international journals (Mashood & Singh, 2012). The final phase of data analysis is under way. A massive pan-Indian survey of our inventory along with three other internationally standardised inventories is currently being carried out.

Additional studies involve an examination of the transferability of general problem solving skills among higher secondary school students and gender studies. The pedagogic potential of physics in this regard was also investigated. The correlation of physics performance of students with their performance in chemistry and mathematics in highly competitive problem solving examinations was studied using a massive data base (half a million students). The gender study showed that the reasonably satisfactory performance by girls in the board examinations does not carry over to more competitive and coveted arenas. While approximately 25% of the candidates appearing for the Indian Institute of Technology - Joint Entrance Examination (IIT-JEE) are girls (one hundred thousand girls out of four hundred thousand, at the time of the study), merely 10% among these female candidates are selected. The Science and Maths Olympiads scene is also bleak in this respect (Singh & Pathak, 2007).

6.1.7 Conferences and seminars

An International Conference on Education in Chemistry (ICEC)

This conference has been initiated in collaboration with the Association of Chemistry Teachers (ACT) in year 2010. The main thrust of the conference is to expose chemistry teachers to different teaching methodologies, e-materials and other digital resources useful for teaching and learning of chemistry, various assessment and evaluation methods and designing of meaningful laboratory courses for chemistry education at tertiary level. The first conference was attended by around 150 chemistry teachers teaching chemistry at undergraduate level. The second is planned for 2014.

NIUS seminar series

A series of seminars under the NIUS project has been initiated in 2013. These seminars delivered by HBCSE personnel and reputed scientists invited from elsewhere are aimed at stimulating scientific discourse at HBCSE, especially at the undergraduate level. Undergraduate students from local colleges are invited to the seminars. Seven seminars have been conducted till August 2014.

6.1.8 Major experimental facilities set up under NIUS

A large number of facilities were set up in each discipline as part of NIUS over the years:

In Biology: UV-VIS spectrophotometer, Gel Documentation system, Cold Centrifuge, Deep Freezer, Poly Acrylamide Gel Electrophoresis Apparatus, Western Blotting, PCR, ELISA Reader were acquired. Using these facilities a number of important projects could be initiated. For example, the DNA profiling of various tissues that differed metabolically could be carried out and studies of protein denaturation , growth parameters of various organisms, model organisms and effects of stress on them and studies of enzymes were undertaken. Projects in computational biology could be initiated also.

In Chemistry: Gas Chromatography, UV-visible spectrophotometers, FT-IR, pH meters (advanced models), refractometer, surface tensiometers (for crude as well as accurate surface tension and interface tension measurement) were acquired. In addition, a computational chemistry facility was set up and advanced software (Gaussian) was acquired for the theoretical study of molecules and clusters. These facilities enabled several important projects to be launched. For example, spectral studies of systems involving nanoparticles, organic and inorganic complexes, surfactants, dyes, study of micellar systems, simulations of solvent-solute interactions and polymers in solvents, electronic structure calculations, studies on the properties of nanomaterials and other optical devices were taken up.

In Physics: Fibre Optic Spectrometer (Ocean Optics make), He-Ne Laser Sources, Optical Bread Boards, EPROM Programmer, Microprocessor Kit, and Sensors for velocity, acceleration, magnetic field and temperature were acquired. Using the above facilities a number of important projects could be initiated. These included the study of emission, transmission and reflectance spectra as well as photoluminescence. The study of opthalmic lenses could be carried out in a systemic way.

Centralised computational facility

Computational science at the undergraduate level is one of the planned thrust areas of NIUS. For this purpose, a computational laboratory in the classroom setting has recently been installed in the NIUS building at HBCSE. This facility, equipped with thirty high-end computers is being used for student and teacher training purposes. Undergraduate student participants in the NIUS Chemistry winter camp used this facility for a computational chemistry module. At the same time, it is also being used as a high-CPU facility by NIUS Physics students for their research work.

6.1.9 Critical appraisal of NIUS

Undergraduate research

Undergraduate research is the salient feature of the NIUS programme. It is a unique venture in India, in terms of sustained nurture and reach among students of non-metropolitan areas and B.Sc. colleges. While some other institutions have recently started research project programmes for undergraduate students, they are mostly confined to their own students and shorter duration. The NIUS research programme affords a much more extensive training of the student by virtue of its longer two-year duration. Students have the opportunity to read at length about the problem they are working on, to carry out a detailed survey of the literature, and to try out a few avenues of progress on their own, rather than being instructed by the mentor to follow a given path in order to finish the project in a short time. In many cases a substantial part of the work is done by the student at his/her own place of study between the visits, while interacting with the mentor over email. This effectively increases the contact time between the mentor and the student.

Even if other institutes in the country start similar long-term research initiatives as NIUS, that should be taken as a positive impact, and would not indicate redundancy for NIUS. Given the vast numbers of students in the country, there is never enough opportunity for everybody. It would be fair to say that NIUS was a pioneer programme for undergraduate research in India (before the IISERs or NISER and CBS started), and it needs to be continued while adapting suitably to the changing scenario.

It is acknowledged that the number of students who can be assigned research projects is limited by the number of available mentors and the administrative demands of monitoring their progress. One way to get around this problem is to seed research initiatives in the colleges themselves where students can carry out modest projects under the guidance of their teachers. This has been started already under NIUS, and should be pursued more vigorously. Helping other institutions in setting up laboratories and classroom teaching at those places could also provide the ideal testing grounds for new ideas and teaching methods.

Even for those students who are not assigned projects after the first camp, the NIUS experience is an enriching one. The lectures on advanced topics given by experts during the first camp are rare exposures for most of the students. It opens their eyes to the world of research and the linkage between classroom knowledge and the real world. NIUS has already built its niche among students and teachers at the undergraduate level. The good word about the high level of training provided by not only the research component but also its various shorter term workshops is spreading rapidly among institutions across the country. This is evident in the sharply rising number of applications received for the various programmes and the extremely positive feedback received from the participants.

Emphasis on experimental science

NIUS has a strong emphasis on experimental science. It provides students with the opportunity of not only working in well-equipped laboratories, but also of exploring new ideas, "playing around" with the equipment and reagents. It prepares them better for research in experimental science.

Synergy between Olympiad and NIUS programmes

The extended period of the undergraduate research programme allows for extensive training and mentoring of students – ideal complement to the fast-paced Olympiad programme. Further, ideas developed for one are often expanded and used in the other. This is a happy consequence of the overlap of faculty and resource personnel between the two programmes.

Need for faculty and other staff

At present the NIUS programme is severely under-staffed. NIUS faculty also run the Olympiad programme, which causes a great overload. Between these two, there are only six faculty members conducting programmes throughout the year in four disciplines of astronomy, biology, chemistry and physics. Both the programmes could benefit immensely from an increase in faculty strength. Scientific and other support staff also need to be increased. As with the Olympiad programme, NIUS also has an over-reliance on temporary staff, which is too costly in terms of training efforts.

Other aspects

1. While some material for undergraduate education have been produced in the form of lecture notes and experimental kits, this is not adequate.

2. Programmes for teachers in terms of short workshops as well as sustained support have not been adequate.

3. There must be multiple entry points for the students. While a sustained research programme for later year students might not be viable, second and third year students may be involved in shorter term projects and workshops.

4. The number of students that the programme can reach has to be increased. This is especially true for students from colleges and non-metropolitan areas who might

not have other opportunities to be involved either in research projects or remedial workshops.

5. The lack of an efficient office to handle administrative matters. Much time and effort of academic and scientific personnel is wasted on arranging logistical matters, which can be better utilized for academic purposes.

6.1.10 Future plans - NIUS

The NIUS programme has been running at HBCSE for a little less than a decade. In the initial years the main focus of the programme was on undergraduate research, which continues to be its most vital component. However, in later years, with the construction of the new office and hostel buildings and the addition of a couple more faculty members, other programmes have also been started. Today NIUS is ideally situated to make a greater impact on the scene of undergraduate education in the country. But this would be only possible if some vital steps are taken to strengthen the programme. Several new ideas have to be implemented, apart from continuing the successful initiatives.

The undergraduate research initiative has turned out to be a major success overall. One of the measures of the success of the programme is the large number of publications in national and international journals and presentation in conferences by NIUS students. This proves that undergraduate research is viable, and NIUS has the capability to guide it. The need for exposing students to research at an early stage is well appreciated in the literature and is corroborated by the steps taken in this direction by other institutions both within and outside the country. While a component of research is integrated in the course structures of most good universities abroad and the recent institutes of advanced education built in the country (IISERs, NISER, CBS, etc.), that is not the case for a vast majority of Indian universities. At the same time, the research institutions of India are facing an acute lack of bright motivated students. NIUS is trying to make up for this lacuna by providing college students with a flavour of research at the highest level outside their regular course structure. Students going through a typical B.Sc. course in most universities of the country would otherwise seldom have an exposure to research, let alone the opportunity of working in a laboratory at a premier institution. The experience of working on a research problem under the guidance of an experienced scientist can provide an excellent motivation for a young mind to continue further in the pursuit of academic goals. The challenge of thinking through a problem whose solution does not pre-exist, or not even be possible at all, is rarely encountered in a classroom or laboratory course taught in a college. It is a liberating experience for a bright mind and, with proper mentoring, can be turned into a career-defining one. In India, where the need for innovative thinking is paramount, there is no doubt that training students to think out of the box about a problem completely outside the curriculum is vital. However, it is equally important that the research problem given to an undergraduate student is pitched at the appropriate level. A problem that is too difficult, too complicated or too advanced in terms of the required background knowledge may be intimidating and may turn out to be discouraging for the student. This is why a NIUS mentor needs to be perceptive about the general level of education at the undergraduate level and design a problem appropriately for the student. The NIUS faculty of HBCSE have the task of this moderation and choosing mentors carefully. But for this to happen, the faculty themselves need to be involved in research so that they have the correct perspective about exciting research areas and the challenges therein. They cannot act solely as agents of assigning students to researchers in other institutions. Unless they themselves have a research profile, they would not be able to attract good mentors from outside into the programme and would soon lose respect among students also, not to speak about not being able to act as mentors themselves. Thus research in fundamental or applied science by NIUS faculty is vital if the programme is to sustain its vibrancy.

It is obvious that the undergraduate research initiative is the core of the NIUS programme and its unique selling point. This aspect of the programme must be persisted with and strengthened. It should not be the only focus of the programme, but it must remain as an essential component. In order to enlarge the scope of the programme, it is necessary to enable other educational institutions to offer research opportunities to their students. Recently established centres like the IISERs already have research components, but colleges, especially in non-metropolitan areas do not. NIUS has an initiative to help teachers in colleges to start research projects themselves where they can train their own students. This avenue needs to be expanded further through academic, material and possibly financial support. However, a careful monitoring of the progress of such projects is necessary.

Among other activities that are envisaged under NIUS in the near future:

1. Holding teacher workshops (more in number and more in topics)
2. Publishing lecture notes (both pedagogical on curriculum topics and on frontline research areas written at the UG level) (started, but to be increased)
3. Developing multimedia modules (to be started)
4. Low cost instrumentation (started, but needs to be developed more)
5. Starting student research on interdisciplinary themes like optics, bioinformatics (to be started)
6. Starting computational science teaching (already in progress)
7. Teacher fellowship programmes (to be started)
8. Collaboration with IISERs and universities on training in experimental physics (started but needs to be pursued)
9. Workshops on training and assessment in the laboratories and developmental teaching strategies (to be started)
10. Specific workshops with students on procedural understanding and instructional strategies (to be started)
11. Continuation of summer workshop on experimental physics (ongoing)

While the main focus of the NIUS program is to motivate and guide students towards mainstream science a modest effort will be directed towards SER and social studies. Concept inventories will be a major effort – they are easy to administer over large groups and analyse. These conditions suit a large and diverse country such as ours. It is also expected that some students in the graduate programme at HBCSE will carry out their doctoral research as part of the Olympiad and NIUS programmes. Another effort will be to have teacher workshops for developing concept inventories. There are invitations already from State Boards to carry this out. A third effort will be to understand and address the special problems of talented students and to devise improved methods to nurture them. Some of us are involved in efforts to organize an International Conference on this issue.

In order to meet even a fraction of the vision of NIUS in improving the educational scenario at the undergraduate level, the most urgent need of the hour is a boost in personnel. One must augment the faculty strength with bright young people capable not only to do independent research in science, but also motivated to train undergraduate students in research, to teach students and to engage with teachers to develop new pedagogical tools. Given the present number of faculty involved in NIUS, it is proposed to recruit at least one faculty member in each of the areas of Biology, Chemistry, Physics and Astrophysics. These are in addition to the requirements of the Olympiad programme. Taking into consideration that the same faculty bears the load of both the NIUS and the Olympiad programmes, we propose to recruit at least two faculty members in each cell over the next five years.

In addition, the number of scientific staff and laboratory staff needs to be increased at least by a factor of two. In order to get rid of the current reliance on temporary staff, positions like laboratory assistants and project assistants need to be made permanent so that expertise can be developed through training over the years.

One of the most pressing needs is the establishment of a permanent NIUS office with at least three office staff who should handle all the logistical arrangements needed for the various activities of NIUS.

6.2 Collaborative Undergraduate Biology Education (CUBE)

(Faculty: G. Nagarjuna; project seeded by the Cognitive Science Research Initiative of the Department of Science and Technology (DST), with Principal Investigator M. C. Arunan)

The Collaborative Undergraduate Biology Education (CUBE) project started as a 5-week hands-on research experience based on 'Simple Model Systems', like daphnia, drosophila, snails, earthworms and crows during the summer 2012. Operating on the no-selection criterion, we had a total of 18 students in the first phase from 4 different colleges in Mumbai and suburbs. Not only the diversity of the colleges (From St

Xavier's College in south Mumbai to much unassuming colleges of the far off suburbs of the Metropolitan Mumbai, like Ulhasnagar and Kalyan), but also the sub-disciplinary diversity of the participants proved to be a great asset for our model of collaboration. With the short-term objective of maintaining these inexpensive, simple model systems, the participants pursued some interesting and sophisticated, front-line research questions on the molecular basis of learning and memory, on epigenetics, regeneration, decision-making, biological rhythms etc.

What happened next is indeed more unconventional. This model of undergraduate research was not just an 'apprenticeship model' in which students were trained in the course of a one-off workshop; it rather had a cascade effect: more colleges were continuously being roped in. Each of the participating colleges was required to establish a "simple model systems" based research lab in their respective centres and conduct similar types of workshop for their neighbourhood colleges, to initiate them into Collaborative Undergraduate Biology (CUB) Research. They were encouraged to submit research proposals, in collaboration with students of neighbourhood colleges (and with their respective teachers as CUBE Teacher Fellows) for the Obaid Siddiqi CUB Research Start-Up Award/Grant, a small start-up grant to defray initial expenses to establish model systems. As mentioned earlier, the model systems and the techniques introduced are extremely inexpensive and yet raise sophisticated questions. Developing newer model systems has also been part of the CUB Research program in these centres.

The undergraduate research experience should form a rich learning ecology with student-centric features. The typical features of such an ecology are that it is open-ended, interactive, inquiry-driven, collaborative and context-bound. Such an experience will have high levels of student-student and student-faculty interactions, ready connections of the subject matter to topics of student interest and learning that reflects aspects of scientific inquiry and evidence-based thinking.

We also realize that for any such transformation, it is very important that there are dependable agents who ensure that the reforms get implemented and that these 'change agents' are made an integral part of the process. Unreservedly, we regard that teachers are the key agents of change and hence it is important that the gap between the communities of teachers and researchers is bridged by linking the two in ways that will help to bring the processes of research into teaching and also help teachers to build a research profile. Further, a community of biology educators/ researchers would be built who are willing to integrate evidence-based practices into their teaching.

CUBE model of learning is thus built upon "communities of practice" where teachers, researchers and students are socialized into the practice of research communities through active and sustained engagement and collaboration. Membership in the community forms identity that translates into competence.

Platforms like the online portal http://cube.metastudio.org/ provide a networked learning environment that enables learners to get entry into a common database that can be browsed, retrieved, linked and commented on by users for information on various model systems and at the same time with a prospect of being 'associative producers' by partaking in the kind of research that could be done using these. Through such a networked collaboration with peers and teachers at the same time, learners both provide and receive process-related feedback that would guide the continued revision and restructuring of knowledge.

Another notable impact of the CUBE project was inclusion of BehaviorWatch and Drosophila as a model system in Mumbai University Zoology practical syllabus. Delhi University awarded the taxonomic profiling of motor actions of birds as an innovative project by supporting ten undergraduate students as a part of the CUBE.

Chapter 7

HBCSE's peer institutions

It is important to ask what are HBCSE's peer institutions, both within the country and internationally. This question is important to not only provide rough benchmarks for guiding and evaluating the Centre's work, but also because education within the country is a huge sector that needs inputs several magnitudes of order higher than what a small institute can provide. Hence HBCSE must co-ordinate its efforts with those of other institutions to achieve maximum impact.

7.1 Peer institutions in the country

It is known that within the country, HBCSE is a unique centre for research and development in science and maths education. As the country's nodal centre for the science and maths Olympiads too, we are unique. However, there are institutions working towards similar goals. In terms of research and development in science education at the school level, a few universities and research institutes have had, or are initiating, fledgeling research programs in science or mathematics education. Some overlaps could be found with the work of the National Council of Educational Research and Training (NCERT http://www.ncert.nic.in/) and its regional institutes, with the Delhi University's Central Institute of Education (DU-CIE), Tata Institute of Social Sciences (TISS), National Institute of Advanced Studies (NIAS) and Azim Premji University (APU). Institutions such as *Eklavya* and *Vidya Bhavan Society*, have outreach profiles similar to HBCSE, in terms of support to curriculum and teacher development or science popularisation.

We would like to identify, for each dimension of our work, what are the peer institutions or organisations in the country with a similar profile of activity, and to answer questions such as the following: what is the relation between HBCSE and these other institutions? What is distinctive about HBCSE's work or contribution? What is HBCSE's strength and what are the attributes or parameters that contribute to this strength? It is also important in the long run, for the country as a whole to have more institutions take up the kinds of activities that HBCSE does. Recently, a few IISERs and some IITs have started groups looking at science or technology education. One of the questions for HBCSE is, what should be our role be in supporting or shaping the emergence of such groups?

7.2 Peer institutions internationally

7.2.1 Centres located in universities

For the purpose of providing comparative benchmarks, and to explore possibilities of collaboration, we have begun to identify institutions with a high reputation internationally, that do work similar to HBCSE, and have a similar profile. Many of the leading centres of Science and Mathematics Education are located in Universities, and run large teacher education programmes. A few of these are listed below:

- The Leibniz Institute for Science Education, University of Kiel, Germany, has over 100 members, in different areas of science and mathematics education, besides faculty in educational science and psychology who address fundamental research questions concerning the teaching and learning of sciences and mathematics.
  (www.ipn.uni-kiel.de/index_eng.html)
- The school of education at the University of Witswatersrand in South Africa has Centres and groups specializing in science and mathematics education, and offer specialized teacher preparation programmes in these fields, besides being a leading place for research in mathematics and science education.
  (www.wits.ac.za/Education/).
- The school of education at University of California, Berkeley has two closely related programs in science and mathematics education – the Education in Math, Science and Technology (EMST) and a Graduate Group in Science and Mathematics Education (SESAME), offering masters and doctoral programme specialized in science, mathematics and technology education. Besides a dedicated group of about 8 faculty members, the programs draw on faculty from other departments and centres.

7.2.2 Centres in science research institutes and science departments

Besides the Centres located at Universities, there are also Centres in institutes of research, which are smaller and more focused on research. A Centre with many similarities to HBCSE is the group for science and mathematics education at the Weizmann Institute of Science. The institute, which in turn has many similarities with TIFR, has a Department of Science Teaching consisting of 11 faculty members that carries out research and development in school science and mathematics education, and runs regular programs for professional development of teachers.

The Department of Science Teaching works in co-operation with the Davidson Institute of Science Education, the educational arm of Weizmann Institute, which is dedicated to promoting science education in Israel, influencing the educational system and spreading scientific knowledge and thinking in the society. The Davidson Institute holds programs for outstanding students, underachieving youth and youth at risk. It holds science competitions and Olympiads, organizes public lectures and science festivals.
(http://stwww.weizmann.ac.il and http://davidson.weizmann.ac.il/en/)

The Freudenthal Institute for Science and Mathematics Education is part of the faculty of science of Utrecht University in the Netherlands. They have a staff of around 80 including researchers and project and support staff. The institutes' mandate includes R&D in science education, teacher education and science communication.
(www.fi.uu.nl/en)

Besides these Centres, which have some overall similarity with HBCSE, there are several others which run programmes that have similarity with specific programmes at the Homi Bhabha Centre. These include the MIT Media Lab, that implements constructionist pedagogies in its programmes for designing learning materials, the Citizen Cyberscience Centre which promotes the use of Citizen science in developing countries and the Nuffield Foundation which develops inquiry based STEM education. In discipline-based educational research, physics is represented most prominently, with physics education research groups at several universities. The oldest and most notable among these is the Physics Department of the University of Washington at Seattle.

Faculty at HBCSE have individually established links with a few of the institutions mentioned above. However we need to have a better shared understanding, sustained interactions and ongoing reflection on our relationship with, and our standing with regard to, our peer institutions within and outside the country. They provide the means to benchmark ourselves and our achievements.

Chapter 8

Defining an identity

8.1 Goals and vision

HBCSE's goal is to enhance the quality and extend the reach of science and mathematics education in the country. Our vision is to be the country's pre-eminent resource for new ideas and expertise, and a world class R&D centre in science and mathematics education.

Forty years after its inception HBCSE remains a unique institution of its kind, charged with the above very broad mandate. In these years HBCSE has taken up a large number of short and long-term activities and fulfilled a range of expectations and demands made on it by government departments and institutions, non-governmental organisations, school groups and even individual schools and teachers. Amongst all of these activities it has become crucial for us to find coherence, focus and a shared sense of institutional purpose: in short, to define an identity for HBCSE.

8.2 Institutional strengths

HBCSE's spectrum of activities is vast, but viewing them together one can distinguish some core competencies of the institution. We must recognise and appreciate these competencies, in order to direct them towards achieving our goals.

The first and the most obvious of our competencies is, an expertise in the basic sciences. It is this expertise that gives us the credibility to carry out in-service teacher education, to develop and advocate new curricula and methods of teaching, to popularise science and mathematics, to provide leadership to the olympiads in India, and to spearhead the National Initiative on Undergraduate Science (NIUS).

Our next competency, and strength as an institution, is an abiding curiosity about science and mathematics education. This curiosity compels us to look beyond the subject matter of science, towards the learner, the teacher and the sociocultural ethos that shapes the context of school and college education in our country, and internationally. It gives us the confidence to forge links between science education and the foundational disciplines of history and philosophy of science, cognitive science, and sociology of science and education. This has resulted in us pioneering research in science, mathematics and technology education in the country. It has motivated us to consistently explore and develop theoretical and experimental problem solving as tools of learning and assessment in science and mathematics.

Our final and most important institutional strength is a social commitment which has led a number of talented persons, now at HBCSE, to forego the natural option of a career in science, and choose the uncertain path of science education. This commitment leads us to address, in many varied ways, the problems of less privileged students: to situate our research in such contexts, to probe the roots of inequity and, in practical ways, to focus on indigenous, low cost solutions; to develop materials aimed to reach large numbers; to work with national level teacher associations; to direct our UG level outreach towards non-metropolitan colleges, and to help teachers from South Asia to initiate participation of their countries in the olympiads.

These are the strengths and competencies that we bring to HBCSE. The institution in turn, in the liberal academic tradition of TIFR, offers its members a congenial atmosphere with freedom and flexibility to pursue a range of interests in a variety of different areas related to science and mathematics education. In striking comparison with other government and non-governmental institutions in the country we are fortunate to have reliable funding (base funding from DAE and project funding from MHRD and DST), a supportive administration and an enlightened lack of bureaucratic procedures.

8.3 A vision articulated two decades ago

In February 1993, soon after HBCSE relocated from Nana Chowk to its present campus in Anushaktinagar, Arvind Kumar and H. C. Pradhan wrote an eloquent and perceptive document titled, ‘Vision of Future HBCSE’ (A. Kumar & Pradhan, 1993). This document articulated a “bifocal social perspective” for HBCSE, which was consistent with the basic tenets of the National Education Policy (NPE), 1986 - “universalisation up to school level for ensuring social equality, and excellence promotion in higher education for ensuring professional manpower for the country.” The authors cautioned however, “These twin foci should not be regarded in opposition to each other; they are complementary and mutually reinforcing.” (A. Kumar & Pradhan, 1993) (p.7) This vision document warned of the danger of large scale field projects overwhelming the basic research ethos of HBCSE. It advocated a strong promotion of academic values, comprehensive graduate course work, and a “plus two” wing offering all India programs including olympiads in different subjects. For achieving large-scale and tangible impact the document advocated “a vigorous emphasis on materials production... (to condense) ...the educational insights and innovations developed by HBCSE through years of fieldwork... (though it be) ...a laborious, time-consuming and ‘painful’ activity.” The document argued passionately that we must “zealously guard HBCSE’s basic identity as a research institution, and insure it against becoming a mere non-professional service organization.” (A. Kumar & Pradhan, 1993) (p.24). In the present document we must recall this vision as it was articulated more than two decades ago:

> ...our vision of future HBCSE involves a symbiosis of elements in many different ways. In terms of social goals, it is a symbiosis of two basic drives: universalisation for equity and excellence promotion for modernization in India. In terms of activity profile, it involves a symbiosis of research, materials writing, fieldwork and science dissemination all feeding and reinforcing one another. In terms of personnel, we envisage a group of cognitive and social scientists, educators, discipline experts and science disseminators in symbiotic relationship with one another. (A. Kumar & Pradhan, 1993) (p.14)

8.4 An R&D Centre

HBCSE’s identity as an interdisciplinary centre for research and development in science and mathematics education was inherent in the conception of its founders. More than being an academic exercise this R&D is closely coordinated with practice and action, an idea that is illustrated in Figure 1.2 of Section 1.1. Our premise has been that an interaction between research, development and practice (or action or outreach), leads to high-quality work in education. Educational practice provides a natural context and opportunities for studying the processes of learning and teaching; development of educational materials occurs in the context of practice and needs trials on groups of students and teachers to get feedback; and the resulting research and materials feed back to enhance outreach and teaching activities. This is an idealised view, but one that has been validated in HBCSE’s experience.

One might reasonably ask whether the expectation to carry out world class high impact research is compatible with simultaneously developing quality teaching materials and conducting regular camps for students and teachers. The answer is: yes, it is a challenge in the present small-sized and short-staffed groups comprising of single faculty members guiding scientific staff and/or research students, though supported by temporary project staff. The synergy that we value and expect may only come about through building of larger and longer-term collaborative groups of permanent and visiting faculty, post-docs, scientific staff, students and project staff.

8.4.1 Research and development

Science, technology and mathematics education have emerged as distinct academic sub-disciplines with their own research journals, conferences and research communities. As a research centre, a primary goal for HBCSE is to grow these sub-disciplines by contributing key theoretical and empirical insights, and by building a community of researchers through its graduate programme and research conferences. Keeping in view the practice-oriented nature of science and mathematics education, an organic connection between research and other dimensions of the Centre's work – resource development, outreach and advocacy needs to be fostered. Further, science and mathematics education are inter-disciplinary areas that draw on subject expertise in science and mathematics, inherit concerns and sensibilities from the larger discipline of education, and apply theoretical insights from allied disciplines such as cognitive science, social science and philosophy. It is hence necessary to build such inter-disciplinary strengths to the extent possible in the faculty profile, and in the research contributions of the Centre.

At the present time, HBCSE is recognized as a, perhaps the, leading institution in the country having expertise in research in science and mathematics education. This has happened through a focused research programme, the strength of disciplinary expertise in the faculty, and a commitment to integrate research with meaningful development and outreach activities. A small body of research contributions have been recognized internationally, and links have been built with the larger international research community through collaborations and participation in conferences. The epiSTEME series of conferences also serve to raise the profile of HBCSE nationally and internationally, besides giving a platform to grow the STME research community in the country.

However given the faculty talent and the financial resources of the Centre, the research contribution could be much higher. Several factors possibly contribute to this situation, and they may all need to be addressed. Firstly, the load of a large number of outreach programmes, which have grown in response to the great demands placed on the Centre by outside agencies, may lead to a focus away from research. It may be necessary to trim such programmes, and bring coherence into them by necessarily connecting most or all outreach activities with research programmes. Secondly, at the moment, the bulk of research activity is centred around graduate students with most research studies linked to Ph.D. dissertations. Hence research programmes are shaped to a great extent by graduate students' interests, which has not led to sustained and focused long term research programmes. What is needed are long term research programmes, with research activity primarily led by faculty members. This may entail that faculty members carry less of the burden of outreach and organisational activities and focus on graduate teaching and their own research. It may also entail that scientific staff contribute centrally to research activity, which is not the case at present. This will result in core teams composed of permanent HBCSE members driving significant research programmes.

Several other measures by which research can be strengthened may need to be implemented. These included targeting high-impact international journals as the primary publication platform, while also retaining dissemination through a larger variety of publication platforms to multiply impact, especially within India. This may entail setting aside resources for open publishing in high-impact journals. Longer academic visits to leading STME research centres in the world by faculty and graduate students, invitations to prominent STME researchers to visit and give courses in specific areas, focussed collaborative work, and opportunities to host leading international conferences (such as PME) need to be strengthened.

The Centre has had, in the past years, a healthy rate of publishing science and mathematics education resources for students and teachers, as a part of its development activity. High quality translations into Indian languages would enable better distribution of these resources around the country. Wide distribution with processes such as internal and external peer reviews will enhance the quality of these resources. Further, their links with the research activity of the Centre must be strengthened. We envisage a situation where outreach and development activities are satellite activities around a core of research programmes.

Finally, we need to examine channels by which we can forge better links with the educational mainstream. Teacher education is central to the identity of education as a discipline both in India and internationally. HBCSE needs to envision its programmes to make better links with teacher education. An alternative that needs to be explored is running innovative teacher education programmes such as B.Sc.Ed. and M.Sc.Ed., possibly in collaboration with other institutions in the neighbourhood.

8.4.2 Olympiads

Across the world the olympiads are seen as high level competitions in science and mathematics aimed at inspiring young people with challenging theoretical and experimental problem tasks. The international olympiads are also valued for cultural exchanges and building of friendships between students living in different countries.

In the present post-school and college scenario which is dominated by a plethora of competitive exams the olympiad selection process takes on great, perhaps too much, importance. The process calls for meticulous planning of each step to achieve a tight control on the outcomes. With a remarkable combination of voluntarism and professionalism the science teacher associations handle the first stage of this process (Section 5.3 and Section 5.7). In fact the entire olympiad process till the last stage of pre-departure training of teams is crucially dependent on teams of dedicated college and school teachers.

This large-scale and, at the final stage, intensive involvement of teachers, presents the possibility that this organized and disciplined series of selection tests may actually carry within it the seeds of a national 'Olympiad movement'. The olympiads have the potential to promote experimentation, innovation, problem solving and critical thinking among students and teachers. With the right policies and priorities (including teacher empowerment in the selection process) this message of the olympiads could reach a larger number.

For HBCSE as an R&D centre for science education, the olympiads stimulate and sustain a year-round development of experimental, observational and theoretical problem-solving tasks. The experimental science and observational astronomy component exists only in the olympiads (albeit at the final stage only), and not in any other selection exam. So far the main mode of dissemination of these materials has been through compilations of problem sets and solutions distributed in print form. Peer reviewed and popular articles are also published (Section 5.5; (Mazumdar, 2014)). Electronic distribution of the tasks is not done to avoid its misuse by coaching classes. With collaborations across groups some creative solutions may be found to develop pedagogical and enrichment materials organised by themes or concepts or core topics which could then be disseminated widely in several Indian languages. A recent booklet "The Olympiads - An Invitation", brought out in English and Hindi (with more bilingual versions planned) is a step towards such dissemination.

Such developmental work may form a good basis for building research programs which could attract Ph.D. students. Already in the 1993 document some research areas had been suggested: "cognitive constructs in advanced science, expert-novice differences and instructional proto-research" (A. Kumar & Pradhan, 1993). Some of these studies have also been carried out.

There is an expectation, particularly from the funding agencies, that the olympiads will induce students to take up science careers and eventually join research institutes in the country. The incidence of olympiad students taking up research careers may vary across subjects (for astronomy see Section 5.10). Data from other subjects is being compiled for presentation at the review. However we recognise that family and peer pressure drives students towards professional courses like medicine and engineering. Their chances of returning to the country after study abroad (which many students opt for) are determined by social forces which are largely beyond our control. Thus we may have to look elsewhere for long-term impact of the Olympiad program: hence some possibilities are suggested above.

8.4.3 Undergraduate education

It is now just about decade since HBCSE entered the field of undergraduate science education, via the NIUS program (Section 6.1). The stated aim of the NIUS program is to revitalise science education in Indian colleges and its main approach has been to expose college student to research at a high level, through mentorship by scientists in top research institutes, like TIFR, BARC and IISERs. In addition, research projects are seeded and supported in colleges and university departments through collaborations and assignment of students to mentors in these departments. In such cases laboratory facilities may be offered on the HBCSE campus. A good number of NIUS students also carry out state of the art research projects under the mentorship or co-mentorship of HBCSE faculty.

8.4.4 An alternative model of undergraduate research

'Undergraduate research' is a term that is variously interpreted around the world. The Association of American Colleges and Universities (AACU) sees it as a vehicle for deeper, more engaged learning of the regular science curriculum, a viewpoint that is elaborated in several documents[1,2]. There is evidence for effectiveness of this approach in student learning, attitude and career choice[3]. This approach has some similarity with what is termed as "proto research" in the original NIUS proposal (A. Kumar, 2003), with the additional aspect of close relationship with the undergraduate curriculum. At HBCSE such an approach would also generate good problems at the undergraduate level and hence feed into experimental and theoretical development for the Olympiads.

8.4.5 Models of mentorship

A large number of peer-reviewed publications have resulted from NIUS in physics where there have been strong pre-existing research programs and collaborations with TIFR and other leading institutes (Mazumdar, 2014). These conditions are not replicated in other areas. Also, given that the goal of the NIUS program is primarily educational, considerable effort spent by the faculty in all subjects in mentoring undergraduate students to reach the required level. Similar mentoring, carried out in institutes like IISc, IISERs and IITs and through visiting students programs in science research institutes, is facilitated by the existence of research groups that include Ph.D. students and post-docs. The mandate of these institutes is to create an ecosystem for the pursuit of science at the frontiers, while running full-fledged undergraduate teaching programs. Such a mandate is absent at HBCSE.

8.4.6 R&D in undergraduate science

HBCSE's mandate is to carry out research and development in science education (including mathematics and technology education). Sustained programs need to be built up in these areas. A model in which faculty carry out independent research projects in diverse areas of science may not be practicable or desirable for future HBCSE. The danger is that HBCSE might become an incoherent collection of science research groups of unsustainable quality, at the cost of its leadership role as an institute that generates valuable expertise, resources and ideas for the education system.

The approach to undergraduate research suggested in Section 8.4.4 is more pedagogical. It may also be extended to research-based development in undergraduate science education, as in physics education at the University of Washington or chemistry education at Purdue[4]. Some physics education research is already carried out (Section 6.1.6) and also developmental work in experimental physics as part of NIUS (Section 6.1.4). Chemistry education research is being initiated along with the ICEC conferences (Section 2.10) and biology education research is also beginning (Mazumdar, 2014). Such programs will enable NIUS students at HBCSE to take up pedagogically motivated ex-

[1] "Undergraduate Research - What is it?" by Asim Gangopadhyaya; Proceedings of The World Conference on Physics Education 2012, Pegem Akademi, ISBN 978-605-364-658-7, February, 2014 Ankara, Turkey.

[2] http://serc.carleton.edu/introgeo/studentresearch/What.html

[3] http://www.niu.edu/engagedlearning/research/pdfs/ugr_high_impact_activity.pdf

[4] http://www.chem.purdue.edu/chemed/

perimental and theoretical projects in conceptually challenging areas of undergraduate physics, chemistry and biology. They would gel well with the Science Education graduate school and the mentorship might be carried out by faculty together with Ph.D. students and post-docs. The result would be a strengthening of R&D at higher secondary and undergraduate levels by allowing faculty to move across the NIUS and the science education graduate school. Further, such R&D programs, if taken up in collaboration with science colleges and motivated college teachers, could effectively improve the quality of science education at undergraduate level.

Other aspects of the NIUS program like, mentorship by scientists around the country, student camps and local study circles, are entirely compatible with this R&D approach.

The vision of NIUS outlined here is partly at variance with the vision in Section 6.1. That section brings out well the educational aspects of NIUS. At the same time it argues strongly that HBCSE faculty involved in the NIUS program should necessarily carry out research in fundamental and applied sciences, while also taking up more training and mentoring programs (Section 6.1.10). This contradiction in the document reflects a lack of consensus in the faculty. In a rejoinder to an earlier version of this chapter some of the NIUS faculty have observed that pedagogically motivated projects are found unattractive by undergraduate students who are more excited by pure science rather than by pedagogical problems. Nonetheless experiences of peer groups worldwide do show us ways to prepare for and attract students to science through pedagogical problems (e.g. cited in Section 8.4.4). Another viewpoint expressed in this context is that each faculty must be given a core assignment and then allowed sufficient latitude in intellectual pursuits. This view goes beyond building a research profile for NIUS mentoring of a few undergraduate students to allowing inquiry into any field of a member's choice.

And yet, towards forging our identity as a world-class R&D Centre we must decide: which are the frontiers that we want to push back? Are they the frontiers of science or of science education? In which domain do we aim to be the leaders? With a clear institutional sense of purpose we must determine where to direct our best intellectual effort, in which fields to strive to achieve excellence.

8.4.7 Professional recognition

The identity issue really goes beyond HBCSE: science education as a field is only very slowly being professionally recognised in the country (Section 2.12). Communities interested in improving science education include NGOs working on the field who focus on development and outreach and also scientists and mathematicians who may have intuitive ideas about teaching and mentoring. Educationists and education researchers on the other hand rarely focus on problems of science education. Development of curricula, textbooks and other teaching resources is not seen as a professional activity requiring long-term commitment. Despite HBCSE's efforts in this direction (eg. see Section 2.4.4 and Section 2.11), a peer group for research and research-based development in science and mathematics education is still lacking in the country.

As a result, the variety of job opportunities that exist for a Ph.D. in science education is not great. Some newer education programs and departments (Tata Institute of Social Sciences (TISS), Azim Premji University (APU) and Ambedkar University) have offered positions to our Ph.D.s. Most older departments, and even new institutions like IISERs do not yet admit the possibility. HBCSE has an application pending with the National Council of Teacher Education (NCTE) to recognise Ph.D. in science education as permissible qualification for teacher educator's position. The reason for the lack of recognition by NCTE is that B.Ed. and M.Ed. are still compulsory prerequisites for teacher educator positions.

Teaching positions in science departments are another possibility. Well-known physics education groups in the United States are located in departments of physics. Such trends need to be initiated in our country. A possible starting point for seeking recognition may be faculty fellowship programs like DST's INSPIRE Fellowship and the UGC's Faculty Recharge Programme and D. S. Kothari Fellowships. Opening up such avenues in the Indian context would require continued advocacy efforts which would show returns only in the long term.

8.5 Future directions

In this review and vision document we have attempted to achieve a balance between reporting, critical appraisal and vision formulation. Yet perhaps there has been more of a component of reporting and a highlighting of our achievements. It is after all a challenge to turn the critical gaze towards oneself, that too in a collective exercise like this self-review.

We do find that our science education research needs to be strengthened from the perspective of science as well as education. Extending our research areas into higher secondary and undergraduate education, effectively relating them to the Olympiad and NIUS programs, would draw more faculty into the graduate school, thus strengthening research programs. At the same time linkages of this research with the foundational disciplines need to be strengthened. In the past we have addressed this issue by inducting faculty members from the areas of psychology, philosophy of science and, more recently, cognitive science. We should assess the scalability of this approach, at the same time working to develop professional links with broad-minded academics across the natural, behavioural and social sciences, as well as the arts and humanities.

The other important linkages to be nurtured are with school systems, voluntary organisations (NGOs) and teacher organisations who would provide a testing ground for our ideas. It is a striking fact that most of the science and maths education centres around the world (Chapter 7), are located in universities or university departments, or run their own teacher education programs. This linkage to teaching adds to the vitality of any program. Our small scale graduate program and also the Olympiad and NIUS programs offer few regular teaching opportunities. Continuing engagements with one or two schools and undergraduate institutes could be explored to fill this gap. Possibilities at the teacher education level have also been suggested (Section 8.4.1).

Given the success of several programs at the Centre, there is a natural tendency towards scaling up. However for a small Centre with limited resources, scaling up will be severely constrained at all times. For a large country like India, it is also important that HBCSE seeds capability in other institutions and establishes strategic partnerships with some, rather than taking on itself the responsibility of reaching larger sections. Scaling up of activities and uncritical diversification, precludes deeper reflection on existing activities and ways of raising them to a greater power. It is also imperative that all major activities of HBCSE be informed by research, indeed incorporate a research dimension that investigates issues and possibilities at a more fundamental level and draws on the best scholarship available internationally.

Finally we have to face up to the fact that the campus at Mumbai will, in a few years, reach its capacity. The projected total faculty strength at HBCSE is 25. Given this strength, we must consider carefully the profile of research, development and outreach activities that can be sustained on the Mumbai campus. Further initiatives may be taken in TIFR's Hyderabad campus.

8.5.1 Plans for the Hyderabad campus

In January 2009 a Government Order allotted to TIFR 209 acres of land contiguous to the campus of the University of Hyderabad. The project proposal for the new campus includes, unification of traditional disciplines under common themes, convergence of fundamental and applied sciences, facilitating new technologies, unification of teaching and research and, a "vigorous programme in science education." The TIFR Centre for Interdisciplinary Sciences (TCIS), established as the first centre of TIFR-Hyderabad, is expected to incubate a broad set of activities to allow seeding of future programs[5]. The activities of TCIS already include science outreach. On the HBCSE model such activities may be deepened and extended to development and research in science education. These activities may preferably focus on rural, government and less-endowed schools in the area. The Navodaya Vidyalaya Samiti has a Regional Training Centre close to the TIFR Hyderabad Campus where teacher education programs may be taken up. Possibilities for synergies and research collaborations on the campus of the University of Hyderabad include the interdisciplinary Centre for Neural and Cognitive Sciences (CNCS), an upcoming school of education with focus on new media, the Hyderabad campus of the Tata Institute of Social Sciences (TISS) and planned campuses contiguous to TCIS, of the National Institute of Design (NID) and the Tata Energy Research Institute (TERI).

A proposal for a centre for learning sciences is consistent with the interdisciplinary character of the new campus and its planned facilitation of new technologies. A short version of the proposal as it arises from the current cognitive science work at HBCSE is given in Appendix H. More ideas from the faculty are on their way. These must be conceptualised and followed through in a rigorous, systematic way. This review process is an opportunity for us to take the lead.

[5] http://www.tifrh.res.in

Appendix A

Conference on Science Education, Khiroda

PROCEEDINGS
OF THE
CONFERENCE ON SCIENCE EDUCATION

KHIRODA
JANUARY 17–19, 1978

HOMI BHABHA CENTRE FOR SCIENCE EDUCATION
TATA INSTITUTE OF FUNDAMENTAL RESEARCH, BOMBAY

Proceedings edited by Dr. R. G. Lagu

Conference on Science Education, Khiroda
Tal.: Raver, Dist.: Jalgaon (M. S.)
January 17, 18 and 19, 1978

Organised by :

Homi Bhabha Centre for Science Education,
Tata Institute of Fundamental Research,
Bombay.

Co-sponsored by :

Sane Guruji Vidya Prabodhini. Khiroda
Western Regional Centre (ICSSR), Bombay
State Institute of Education, Pune
Indian Institute of Education, Pune
Municipal Corporation of Greater Bombay
State Institute of Science Education, Pune

Steering Committee :

Prof B. M. Udgaonkar	TIFR, Bombay
Prof. R. R. Daniel	TIFR, Bombay
Shri. V. G. Kulkarni	HBCSE, TIFR, Bombay
Prof. N. K. Chaudhari	SGVP, Khiroda
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Dr. S. D. Kulkarni	IIE, Pune
Mrs. Kusum Kamat	BMC, Bombay
Shri V. R. Nagpure	SISE, Pune
Dr. R. G. Lagu	HBCSE, TIFR, Bombay

Reception Committee :

Shri Madhukarrao Chaudhari (chairman)
(Hon'ble minister for revenue, Maharashtra State)
Shri D. M. (Bhausaheb) Bonde
Prof. J. D. (Bhanu) Chaudhari
Dr. R. G. Chaudhari
Prof. N. K. Chaudhari
Shri M. R. Chaudhari
Prof. M. M. Chaudhari
Prof. M. A. Zambre
Prof. R. K. Mahajan
Prof. M. A. Chaudhari
Prof. R. K. Fegade
Shri P. D. Mahajan

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V) Innovations in Science Education

Chairman : Smt. Kusum Kamat

VI) In-service Orientation of Practising Teachers

Chairman : Dr. R. G. Chaudhari

VII) In-service Orientation of Practising Teachers

Chairman : Sewaram Chaturvedi

Appendix B

Conferences and seminars (1978-2014)

1978 – 1979 Conference on Science Education, Khiroda, Jalgaon, Maharashtra (HBCSE, January 17-19, 1978)

1985 - 1986 Seminar to discuss the document on educational policy released by the Ministry of Education, Government of India.

1989 - 1990 Indo-US Workshop on Mathematics Education, Goa, India. (HBCSE, November 1989).

1991 - 1992 HBCSE co-ordinated the Second Indo-US Workshop on Mathematics Education held in Goa from 3 - 13 February, 1992.

1995 - 1996 International Workshop on the Cognitive Bases of Learning (IWCBL), Mumbai, India. (HBCSE, December 7 - 12, 1995)

1997 - 1998 International Workshop on History and Philosophy of Science: Historical, Sociological, Cognitive and Educational Perspectives, IIT Mumbai, (February 1998).

HBCSE-INSA Seminar on "Lessons from 20th Century Science".

1998 - 1999 History of Science: Implications for Science Education (HBCSE, Mumbai February 22-26, 1999).

2000 - 2001 International Conference on Science Technology and mathematics Education for Human Development (Panaji, Goa, February 20 – 23, 2001).

Perspectives on Mathematics Education. HBCSE, December 16, 2000.

2002 - 2003 Approaches to the Implementation of Multilingual / Multi-expressive Education in India and South Africa. HBCSE, October 17 to 19, 2002.

2003 - 2004 Physics Education : looking ahead. HBCSE, Mumbai, April 9, 2003.

A One day seminar was organized jointly by Indian Physics Association and HBCSE (TIFR).

2004 - 2005 epiSTEME-1, International Conference to Review Research in Science, Technology and Mathematics Education. International Centre, Goa, December 13-17, 2004.

2006 - 2007 epiSTEME-2, International Conference to Review Research in Science, Technology and Mathematics Education. HBCSE, Mumbai, February 12-15, 2007.

SELF Conference, an International Conference on Science, Education and Learning in Freedom, TIFR, Mumbai, February 2, 2007.

SELF Project - International Board Meeting HBCSE, January 26 - February 1, 2007.

Core Group Workshop on Science Education. In collaboration with People's Science Congress, Allahabad. HBCSE, Mumbai, January 22-24, 2007.

2007 - 2008 Conference on Science Education in honour of Prof. B. M. Udgaonkar on the occasion of his completion of 80 years.

HBCSE I-CONSENT Workshop. HBCSE, Mumbai, April 12-15, 2007.

HBCSE Workshop on development educational e-materials in hindi. Vigyan Parishad, Prayag, February 2008.

2008 - 2009 epiSTEME-3, International Conference to Review Research in Science, Technology and Mathematics Education. HBCSE, Mumbai, January 5-9, 2009.

National Workshop on Relevance and Contribution of Lev. D. Landau, J. P. University, Chapra, Bihar, November 20-21, 2008.

Five Open Educational Resources for Schools (OER4S) Project Workshops.

National Workshop on Hindi e-materials. Vigyan Parishad Prayag, February 26 – 28, 2008.

19th International Biology Olympiad 2008. HBCSE, Mumbai, July 13-20, 2008.

2009 - 2010 2nd Peoples Education Congress 2009. HBCSE, Mumbai, October 5-8, 2009.

2010 - 2011 4th Asian Science Camp. HBCSE, Mumbai, August 17-22, 2010.

epiSTEME-4, International Conference to Review Research in Science, Technology and Mathematics Education. HBCSE, Mumbai, January 5-9, 2011.

2nd Indo Swedish Meeting. HBCSE, Mumbai, February 24-26, 2011.

International Conference on Education in Chemistry. HBCSE, Mumbai, November 12-14, 2010.

Open Video Conference. HBCSE, Mumbai, January 23, 2011. A symposium on Pad.ma and Firefox development was held.

Development of educational e-materials in hindi Vigyan Parishad, Prayag, November 26 – 28, 2010.

SED India Meet. HBCSE, Mumbai, January 11-13, 2011.

2011 - 2012 National Initiative in Mathematics Education (NIME). HBCSE, Mumbai, January 20-22, 2012.

2012-13 20th International Conference on Conceptual Structures, HBCSE, Mumbai, 10 to 12, January 2013

epiSTEME – 5, HBCSE, Mumbai, 7 to 11 January 2013

3rd National Workshop on Development of Educational E-Materials in Hindi, HBCSE with Vigyan Parishad Prayag, 2-4 November 2012

2-Day Seminar on Responding to Changing Educational Paradigms, HBCSE, 11-12 October 2012

Asian Physics Olympiad, New Delhi, 30 April to 8 May, 2012

2013-14 10th International Junior Science Olympiad, Pune, 3 to 11 December 2013.

Appendix C

Impact factors of journals

The publications numbers in the Tables below refer to data on research publications available up to March 2014. Given the range of journals included in the Tables the publications in them lie on a spectrum from 'research' to 'pedagogical'. The designation of some of these papers as 'research', and hence their inclusion in the Tables, involves an exercise of judgement of which the reliability is yet to be ascertained. For the intrepid archivist and the curious reader the classified list of papers is kept in the Dean's Office.
– Editors

Table C.1: Impact factors of STME journals.

S. No.	Name of Journal	No.of Pubs	Impact Factor	I = Indian
1	Journal of Research in Science Teaching	1	2.552	
2	Physics Education Research	1	2.302	
3	Acta Psychologica	1	2.2	
4	Journal of Engineering Education	1	1.925	
5	Resonance	10	1.85	I
6	The Quarterly Journal of Experimental Psychology	1	1.82	
7	Physica A	1	1.676	
8	International Journal of Science Education	13	1.34	
9	Research in Science Education	2	1.268	
10	Current Science	3	0.905	I
11	Journal of Mathematical Sociology	3	0.88	
12	American Journal of Physics	4	0.78	
13	Educational Studies in Mathematics	1	0.765	
14	European Journal of Physics	6	0.64	
15	Australian Journal of Teacher Education	1	0.54	
16	Pragmatics and Cognition	1	0.5	
17	International Journal of Technology and Design Education	2	0.339	
18	Journal of Biological Education	1	0.269	

Note: Continued on the next page.

Table C.2: STME journals for which impact factors are not available.

S. No.	Name of Journal	No.of Pubs	Impact Factor	I = Indian
19	Asia-Pacific Journal of Teacher Education and Development	1	NA	
20	Astronomy Education Review	1	NA	
21	CASTME Journal	4	NA	
22	Design and Technology Education: An International Journal	3	NA	
23	Journal of Applied Collaborative Systems	1	NA	
24	Mathematics Teacher	1	NA	
25	Mathematics Teaching-Research Journal	1	NA	
26	Metascience	1	NA	
27	Newsletter of AERA SIG on Subject-Matter Knowledge and Conceptual Change	1	NA	
28	Physics Education (UK)	2	NA	
29	School Science Review	1	NA	
30	Science Activities	1	NA	
31	Staff and Educational Development International	1	NA	
32	Bharatiya Shikshan	2	NA	I
33	Journal of Scientific and Industrial Research	1	NA	I
34	Lab Experiments	1	NA	I
35	Prayas	1	NA	I
36	Bharatiya Samajik Chintan	1	NA	I
37	Chemistry Education	2	NA	I
38	Complex Systems	1	NA	I
39	Computers Today	1	NA	I
40	Contemporary Education Dialogue	2	NA	I
41	DPEP	1	NA	I
42	Education (India)	1	NA	I
43	Indian Educational Review	5	NA	I
44	Indian Journal of Open Learning	1	NA	I
45	Journal of Educational and Social Change	9	NA	I
46	Journal of Indian Education	4	NA	I
47	Man and Development	1	NA	I
48	Mathematics Education (India)	1	NA	I
49	Physics Education (India)	32	NA	I
50	Physics News	1	NA	I
51	Recent Researches in Education and Psychology	2	NA	I
52	School Science (NCERT, India)	6	NA	I
53	Shikshan Ani Samaj	1	NA	I
54	Society and Science	1	NA	I
55	Vidnyan Varta, Special Issue	1	NA	I
56	State Council of Education Research and Training	1	NA	I
57	The Indian Educational Researcher	1	NA	I
58	The Primary Teacher	2	NA	I
59	The Radical Humanist	2	NA	I
60	Vetri Education, Number 1	1	NA	I
61	Vijnana Parishad Anusandhan Patrika	1	NA	I
62	Voices of Teachers and Teacher Educators	1	NA	I
	Total (excluding pedagogical articles/reviews = 80)	160		33

Table C.3: Impact factors of Science journals

S. No.	Name of Journal	No.of Pubs	Impact Factor	I = Indian
1	Science	1	31.027	
2	The Astrophysical Journal	1	6.733	
3	The Astrophysical Journal Letters	1	6.345	
4	Journal of High Energy Physics	1	5.62	
5	Monthly Notices of the Royal Astronomical Society	4	5.521	
6	Journal of Physics G	2	5.326	
7	Astronomy & Astrophysics	5	5.084	
8	Astronomy and Astrophysics Supplement	1	5.084	
9	Journal of Physical Chemistry C	1	4.814	
10	Physical Review D	6	4.69	
11	Physics Letters B	1	4.569	
12	Physical Review B	4	3.767	
13	Physical Review C	10	3.72	
14	Journal of Chemical Physics	2	3.164	
15	Physical Review A	3	3.042	
16	Journal of Physical Chemistry A	1	2.771	
17	Publications of the Astronomical Society of Japan	1	2.438	
18	Journal of Physics Condensed Matter	1	2.36	
19	Journal of Lumin	1	2.144	
20	Astrophysics and Space Science	1	2.064	
21	European Physics Journal A	1	2.04	
22	Journal of Physics B	1	2.031	
23	Resonance	1	1.85	I
24	Indian Journal of Physics	1	1.785	I
25	Journal of Physics A	1	1.766	
26	Physics Letters A	1	1.766	
27	Solid State Commun	1	1.534	
28	Astronomische Nachrichten	5	1.4	
29	Journal of Mathematical Physics	2	1.296	
30	International Journal of Modern Physics A	3	1.13	
31	American Journal of Physics	1	0.782	
32	Pramana	4	0.562	I
33	Acta Physica Polonica B	1	0.34	
34	Journal of Physics: Conference Series	1	NA	
35	Acta Supp 1, Proceedings in Radiochemistry	1	NA	
36	Indian Journal of History of Science	2	NA	I
37	Material Research Express	1	NA	
38	Prayas	3	NA	I
39	Puratatva	1	NA	I
40	SMC Bulletin	1	NA	
41	IAPT Bulletin	1	NA	I
	Total (excluding reviews = 25)	82		7

Appendix D

Science Education PhD Titles

Titles of Ph.D. theses and recent research proposals in Science Education submitted to TIFR Deemed University

D.1 Theses

1. Understanding the underlying cognitive mechanisms of the problem solving approaches of introductory physics students
   Mashood K.K., November 2009; Advisor: Vijay Singh (from 2011)

2. Investigating Students', Teachers' and Designers' Ideas about Design and Developing Design Activities for Indian Middle School Students
   Farhat Ara, April 2013; Advisor: Sugra Chunawala

3. Cognitive Studies in Relativity
   Atanu Bandyopadhyay, April 2011; Advisor: H. C. Pradhan & Arvind Kumar

4. Spatial Cognition and Visualization in Elementary Astronomy Education
   Shamin Padalkar, September 2010; Advisor: Jayashree Ramadas

5. Visual Depictions and Mental Visualisation of Human Body Systems in Middle School Students
   Sindhu Mathai, September 2010; Advisor: Jayashree Ramadas

6. Understanding Causality in Natural Selection: Towards the Problematic of Learning Darwin's Theory of Evolution
   Abhijeet Bardapurkar, July 2008; Advisor: G. Nagarjuna

7. Investigating Middle School Students' Perceptions of Technology and Developing Design and Technology Education Units to Study Students' Design Productions
   Ritesh P. Khunyakari, July 2008; Advisor: Chitra Natarajan

8. Introducing Indian Middle School Students to Collaboration and Communication Centred Design and Technology Education: A Focus on Socio –Cultural and

Gender Aspects
Swati Mehrotra, July 2008; Advisor: Sugra Chunawala

9. Developing a Learning Sequence for Transiting from Arithmetic to Elementary Algebra
   Rakhi Banerjee, April 2008; Advisor: K. Subramaniam

D.2 Ongoing Research Proposals

Information on the proposal title, student, advisor, month and year of registration along with submission of proposal are given below.

1. 'Open-Beginninged' Science Explorations: Students' Questions, Methods of Investigation, and their Interrelations
   Gurinder Singh, September 2014; Advisor: Karen Haydock, Co-Advisor: K K Mishra

2. The Cultivation of Cultivation: Understanding the Relationships between Agriculture, Farmers' and Scientific Methods, and Education
   Rosemary Varkey, July 2014; Advisor: G. Nagarjuna

3. The cognitive role of external representative in understanding DNA structure
   Anveshna Srivastava, July 2012; Advisor: Sanjay Chandrasekharan

4. Investigating representational competence in chemistry across groups with varying academic exposure
   Prajakt Pande, February 2013; Advisor: Sanjay Chandrasekharan

5. Teaching, learning and assessment of elementary mathematics through a collaborative, constructive and distributed instant messaging environment
   Rafikh Shaikh, July 2013; Advisor: Nagarjuna G.

6. Children's Understanding of Measurement Concepts
   Jeenath Rahaman, September 2011; Advisor: K. Subramaniam

7. Developing Teachers' understanding of students' mathematical thinking through classroom based tasks
   Shikha Takker, September 2011; Advisor: K. Subramaniam

8. Designing learning contexts for understanding & facilitating qualitative to quantitative knowledge using Model-based reasoning
   Shraddha Ghumre, November 2011; Advisor: G. Nagarjuna

9. Inclusive science education in elementary & secondary schools with a focus on strategies for reaching science to children with visual impairments
   Amit Sharma, February 2011; Advisor: Sugra Chunawala

10. Connecting school mathematics and 'Everyday Mathematics' in the Domain of Multiplicative Thinking
Arindam Bose, May 2010; Advisor: K. Subramaniam

11. Conceptualizing ' Science Education for all' with a focus on understanding students' negotiation of socioscientific issues
Aswathy Raveendran, March 2010; Advisor: Sugra Chunawala

12. Project based learning: Development and implementation of project and assessment
Saurav Shome, March 2010; Advisor: Chitra Natarajan

13. Investigating the effects of an inquiry science classroom: Behavioural and attitudinal changes in children
Aisha M. Kawalkar, April 2009; Advisor: Jyotsna Vijapurkar

14. Exploring critical graphicacy in schools with studio thinking approach
Amit Dhakulkar, May 2009; Advisor: G. Nagarjuna

15. Collaborating with teachers to develop classroom practices aimed at teaching mathematics for understanding
Ruchi S. Kumar, April 2009; Advisor: K. Subramaniam

16. Effectiveness of refined concept mapping technique for science education
Meena Kharatmal, September 2006; Advisor: G. Nagarjuna

17. Students' Alternative conceptions in Heat and Thermodynamics
Shirish R. Pathare, September 2006; Advisor: Savita Ladage

18. Designing Learning Activities to Facilitate Understanding Physical Geography: Developing Learner Competencies among High School Students
Deepak S. Paranjape, May 2007; Advisor: S. C. Agarkar

19. Pedagogy of Special Relativity
Imrankhan P. Pathan, September 2006; Advisor: Sugra Chunawala

Appendix E

Books by HBCSE members

The lists include books and reports available with the HBCSE publication section.

Table E.1: Homi Bhabha Curriculum: Small Science, and Environmental Science

S. No.	Title	Cost Rs.	Lang	Pub Year	Author
Homi Bhabha Curriculum: Small Science					
1	SS I/II Teachers Book	23	English	2004	J. Ramadas, A. Kawalkar, S. Mathai
2	S.S.Class-3 (T/Book)	40	English	1998	J. Ramadas
3	S.S. Class-3 (W/Book)	40	English	1998	J. Ramadas
4	S.S. Class-4 (T/Book)	45	English	2001	J. Ramadas
5	S.S. Class-4 (W/Book)	55	English	2001	J. Ramadas
6	S.S. Class-4 (Teach H/B)	37	English	2008	J. Ramadas
7	S.S. Class V (Eng) Text Book	40	English	2003	J. Vijapurkar
8	S.S. Class V (Eng) Work Book	25	English	Nil	J. Vijapurkar
9	Small Science V Teachers'Book	55	English	2006	J. Vijapurkar
10	SS I/II Teachers Book	17	Marathi	2010	J. Ramadas, A. Kawalkar, S. Mathai, Trans: D. Palshikar
11	S.S. Class-3 (T/Book)	15	Marathi	2011	J. Ramadas, Trans: Shivali Tukdev
12	S.S. Class-3 (W/Book)	16	Marathi	1999	J. Ramadas, Trans: Shivali Tukdev
13	S.S. Class-3 (Teach/H/B)	35	Marathi	2008	J. Ramadas, Trans: Shivali Tukdev
14	S.S. Class-4 (T/Book)	14	Marathi	2002	J. Ramadas, Trans:D. Palshikar
15	S.S. Class-4 (W/Book)	20	Marathi	2002	J. Ramadas, Trans:D. Palshikar, Shobhana Bhide
16	S S Class-4 Teachers Book	37	Marathi	2010	J. Ramadas, Trans:D. Palshikar
17	S.S. Class-3 (T/Book)	20	Hindi	1999	J. Ramadas, Trans: K. K. Mishra
18	S.S. Class-3 (W/Book)	13	HIndi	1999	J. Ramadas, Trans: K. K. Mishra
19	S.S. Class-3 (Teach.H/B)	35	HIndi	2000	J. Ramadas, Trans: K. K. Mishra
20	S.S. Class-4 (T/Book)	17	HIndi	2002	J. Ramadas, Trans: K. K. Mishra
21	S.S. Class-4 (W/Book)	22	HIndi	2002	J. Ramadas, Trans: K. K. Mishra
22	S.S. Class-4 (Teach H/B)		HIndi	2007	J. Ramadas, Trans: K. K. Mishra
Curricular Books: Environmental Science					
1	In Harmony With Nature, Teachers' hand book on learning for sustainable living		English		V G Gambhir
2	Maitri Nisargashi, Teachers' hand book on learning for sustainable living		Marathi		V G Gambhir

Table E.2: Homi Bhabha Curriculum: Mathematics

S. No.	Title	Cost Rs.	Lang.	Pub. Year	Author
1	Maths for Every Child -I	140	English	2004	A. T. Mavalankar, H. C. Pradhan
2	Maths for E/ Child (III) P-A	68	English	2001	K. Subramaniam
3	Maths for E/ Child (III) P-B	48	English	2001	K. Subramaniam
4	Maths III Teachers' Guide	25	English	2005	K. Subramaniam
5	Sarvan Sathi Ganit Class-1	100	Marathi	2009	A. T. Mavalankar, H. C. Pradhan
6	Sarvan Sathi Ganit Class II	105	Marathi	2008	A. T. Mavalankar, H. C. Pradhan
7	Maths for All (III) P-A	25	Marathi	2002	K. Subramaniam
8	Maths for All (III) P-B	15	Marathi	2002	K. Subramaniam
9	Maths III Teachers' Guide	25	Marathi	2005	K. Subramaniam

Table E.3: Foundation Curriculum: Science, Technology and Society

S. No.	Title	Cost Rs.	Lang.	Pub. Year	Author
1	F.C.:The Population Problem-1	136	English	1997	Chitra Natarajan
2	F.C.:Resources-Energy-2	136	English	1997	Chitra Natarajan
3	F.C.:Resources-Land & Air-3	136	English	1997	Chitra Natarajan
4	F.C.:Education-4	136	English	1998	G.C. Pal, C. Natarajan
5	F.C.:Global Climate Change-5	136	English	1998	Sanjeev Raj N., Chitra Natarajan
6	F.C.:Ecological Balance-6	136	English	1998	Y. Parab, C. Natarajan
7	F.C.:Conflicts-7	176	English	1999	S. Chunawala, C. Natarajan
8	F.C.:Health Matters-8	176	English	1999	B. S. Mahajan, C. Natarajan

Table E.4: Olympiads

S. No.	Title	Cost Rs.	Lang.	Pub. Year	Author
1	An Excursion in Mathematics	120	English	1993	Edi: V. V. Acharya
2	Challenging Experiments in Chemistry	85	English	2009	S. Ladage, S. Narvekar, Indrani Sen
3	Experimental Probs. In Chemistry	145	English	2009	S. Ladage, S. Narvekar, Indrani Sen
4	Ind Nat Bio Oly Theory Papers 2002-04	90	English	2011	R. Vartak, A. Ronad
5	Ind Nat Bio Oly Theory Papers 2005-07	90	English	2011	R. Vartak, A. Ronad
6	Ind. National Phy.Olymp.Theory Probs.(1998-2005)	60	English	2011	V. Singh, S. Pathare
7	Ind Nat Phy Olympiad Theory Prob & Sol.(2006-2009)	90	English	2008	V. Singh, P. Pathak
8	Interesting Expts.for undgraduate Chem	100	English	2009	Savita Ladage
9	Problem Primer for Olympiads	120	English	2009	C. R. Pranesachar, B. J. Venkatachala, C. S. Yogananda
10	Functional Equations	160	English	2003	B. J. Venkatachala
11	Indian Natioanl Astronomy Olympiad (1999-2008)	100	English	2013	A. Sule, A. Ghaisas, M. N. Vahia
12	Indian National Chemistry Theory Papers with Solutions (2002-04)	160	English	2013	Savita Ladage, Swapna Narvekar
13	Indian National Chemistry Theory Papers with Solutions (2005-07)	160	English	2013	Savita Ladage, Swapna Narvekar
14	Inequalities: An Approach Through Problems		English	2009*	B J Venkatachala
15	Challenge and Thrill of Pre-College Mathematics		English		V Krisnhnamurthy, C R Pranesachar, K N Ranganathan, and B J Venkatachala

Table E.5: Co-curricular and Popular Science Books - 1

S. No.	Title	Cost Rs.	Lang.	Pub Year	Author
1	Aids Booklet	8	English	2001	Alka Dureja, B. S. Mahajan, A. Ronad
2	All About Microscope- History Use & Care	70	English	2010	N. D. Deshmukh, S. C. Agarkar
3	Atoms and Development	90	English	2006	Arvind Kumar, C. Natarajan
4	Chaos Fractals and Self-organisation		English		Arvind Kumar
5	Doing Science in Fun		English		V G Gambhir
6	Experiments are Fun	35	English	1978	R. G. Lagu, H. N. Sethna
7	Fascinating Story of Periodic Table	20	English	2013	Savita Ladage, Tejas Joshi
8	Fun with Buoyancy	45	English	2014	A K Gupta, Ebie Sam, Chitra Natarajan
9	Gender and Science : English	15	English	2003	S. Chunawala
10	General Science Quiz [English]	15	English	2009	N. D. Deshmukh, S. C. Agarkar, V. D. lale, V. C. Sonawane
11	How & Why in Physics (Dinamics) 2		English	1993	Arvind Kumar & S.A. Barve
12	How & Why in Physics (Kinematics) 1		English	1993	Arvind Kumar & S.A. Barve
13	How & Why in Physics (System of Particles) 3		English	1994	Arvind Kumar & S.A. Barve
14	How & Why in Science - Jr. 1	44	English	1978	Ed.: R. G. Lagu
15	How & Why in Science - Jr. 2	44	English	1981	Ed.: R. G. Lagu
16	How & Why in Science - Sr. 1	44	English	1978	Ed.: R. G. Lagu
17	How & Why in Science - Sr. 2	44	English	1981	Ed.: R. G. Lagu
18	Innovative Exptl.Problems. . .	45	English	2002	R. B. Khaparde, H. C. Pradhan
19	Learning Studies		English		
20	Let's Meet the Chemical Elements	230	English	2014	Savita Ladage, Tejas Joshi
21	Mathematics Education in India	130	English	2012	R. Ramanujam, K. Subramaniam
22	Mathematics Posters (Foam)		English		
23	Mathematics Posters (Paper)		English		
24	Mathematics Speaks		English		
25	Novel Experiments	53	English	1985	R.G.Lagu, S.B.Mhetre
26	Roots of Reason		English		
27	Science Experiments for Primary & Middle Schools	40	English	1991	V.G.Kulkarni, R.M.Bhagwat, V.G.Gambhir
28	Science : A Human Saga		English		G. Nagarjuna
29	The Joy of Mathematics		English		
30	Tracking Gastro-intestinal Diseases	6	English	Nil	S. P. Rao D., B. S. Mahajan
31	Tracking the Microbes	6	English	2001	B.S.Mahajan
32	Training in Experimental Physics through Demonstrations	350	English	2009	V. G. Kulkarni, Dr. B. Phondke, Anjali Kulkarni

Table E.6: Co-curricular and Popular Science Books -2

S. No.	Title	Cost Rs.	Lang.	Pub Year	Author
33	Understanding Chemistry		English		
34	We Can Win it		English		
35	Gatha Shodhanchi	175	English/ Marathi	2004	V. G. Kulkarni, B. L. Phondke, A. Kulkarni
36	Inventions and Discoveries	185	English/ Marathi		
37	Water: The Matrix of Life	50	English	2000	K. K. Mishra
38	How and Why in Science		Gujarathi		
39	Gyan-Vigyan Samkalin Shaikshik Nibandh	75	Hindi	2009	Ed.: K. K. Mishra
40	Gyan-Vigyan Shaikshik Nibandh	160	Hindi	2013	K. K. Mishra (Ed)
41	Jal Jivan Ka Adhaar	35	Hindi	2001	
42	Khoje Hue Prashn	65	Hindi	2008	Yash Pal, Rahul Pal; Translation K K Mishra
43	Lok Vigyan Samakaleen Rachanayen	50	Hindi	2006	K. K. Mishra
44	Paramanu Aur Vikas	150	Hindi		K K Mishra (Ed)
45	Science : A Human Saga	90	English	2004	G. Nagarjuna, A. Kumar
46	Sukshma Jivon ki Khoj	6	Hindi	1999	Alka Dureja, B.S.Mahajan, S.Rao D.
47	Vigyan Calendar	2000	Hindi	2013	K. K. Mishra
48	Vigyan: Manav ki Yashogatha	90	Hindi	2004	K. K. Mishra (Trans.)
49	Aaplya Sabhovatali : Marathi	65	Marathi	2008	P. K. Nawale
50	Adhyapan Ganitache -1	65	Marathi	2014	S.C.Agarkar, Arvind Kumar
51	Adhyapan Ganitache -2	52	Marathi	2014	S.C.Agarkar, Arvind Kumar
52	Akash Kase Pahave	170	Marathi	2012	A. D. Ghaisas
53	Aple Vishwa	130/150	Marathi	2009	A. D. Ghaisas
54	Apli Suryamala	130/150	Marathi	2010	A. D. Ghaisas
55	Chaos Fractals and Self-organisation	55	Marathi	1996	Arvind Kumar
56	Durbini Ani Vedhshala	150	Marathi	2009	A. D. Ghaisas
57	Ganit Sadnyakosh-1 (Geometry)	74	Marathi	1994	N.P.Shimpi, A.T.Mavalankar, H.C.Pradhan
58	Ganit Sadnyakosh-2 (Arith-Algebra)	57	Marathi	1997	N.P.Shimpi, A.T.Mavalankar, H.C.Pradhan
59	Ganit Shikshnatil kahi mahatvache vachane	130	Marathi	2010	S.Naik, A.T.Mavalankar
60	Ganitacha Gujhghoshti	28	Marathi	1987	R. G. Lagu, D. T. Tare
61	Gender and Science	15	Marathi	2003	S. C. Chunawala
62	Guidelines for Extn Officers	16	Marathi	1993	V. G. Gambhir

Table E.7: Co-curricular and Popular Science Books - 3

S. No.	Title	Cost Rs.	Lang.	Pub Year	Author
65	Khagolshastradnya	150	Marathi	2012	A. D. Ghaisas
66	Khel Kheluya Vidnyanache	60	Marathi	2002	A. D. Ghaisas
67	Krutipar Vidnyan Adhyapan [Biology]	75	Marathi	2007	N.D.Deshmukh, S.C.Agarkar
68	Krutipar Vidnyan Adhyapan	50	Marathi	2009	V.C.Sonawane, S.C.Agarkar
69	Kumar Vishwakosh	350	Marathi	2011	Ed: Dr. Vijaya Vad
70	Kutuhal : Jr. 1 (8-12)	42	Marathi	1978	Ed.: R. G. Lagu
71	Kutuhal : Jr. 2 (8-12)	42	Marathi	1981	Ed.: R. G. Lagu
72	Kutuhal : Sr. 1 (12-16)	42	Marathi	1978	Ed.: R. G. Lagu
73	Kutuhal : Sr. 2 (12-16)	42	Marathi	1981	Ed.: R. G. Lagu
74	Rem. Sec. Geom Part-1	40	Marathi	2012	S. C. Agarkar, A. Kumar
75	Rem. Sec. Geom Part-2	50	Marathi	2012	S. C. Agarkar, A. Kumar
76	Rem. Sec. Maths Part-1	60	Marathi	1989	S.C.Agarkar, H.C.Pradhan, R.M.Bhagwat, A.Kumar
77	Rem. Sec. Maths Part-2	65	Marathi	1990	S.C.Agarkar, H.C.Pradhan, R.M.Bhagwat, A.Kumar
78	Rem. Sec. Maths Part-3	70	Marathi	1991	S.C.Agarkar, H.C.Pradhan, R.M.Bhagwat, A.Kumar
79	Rem. Sec. Maths Part-4	65	Marathi	1992	S.C.Agarkar, H.C.Pradhan, R.M.Bhagwat, A.Kumar
80	Shalabheti Ani Margadarshan	16	Marathi		
81	Shaley Vidnyanatil Shanka	65	Marathi		
82	Stri Purush Bhed ani Vidnyan	15	Marathi		
83	Students Spont.Concepts (DLIPS)	5	Marathi	1996	J.Ramadas, S.Chunawala, C.Natarajan, S.Apte
84	Teaching of Maths P-1	65	Marathi	1993	R.M.Bhagwat, A.T.Mavalankar, H.C.Pradhan
85	Teaching of Maths P-2	52	Marathi	1996	R.M.Bhagwat, A.T.Mavalankar, H.C.Pradhan
86	Utilizing Vacation ...	40	Marathi	1992	V.G.Kulkarni, S.C.Agarkar
87	Vidnyan ani Tantragnan	100	Marathi	2006	H.C.Pradhan
88	Vidnyan Gamiti	85	Marathi	2008	P. K Nawale
89	Vidnyan Prashna Manjusha	56	Marathi	2004	N.D.Deshmukh, S.C.Agarkar, V.D.Lale, V.C.Sonawane
90	Vidnyan Shikshan Navya Vata	160	Marathi	2004	H. C. Pradhan
91	Vidyarthi Vyakti. Vikasasathi Suttyancha Sadupayog	40.00	Marathi		
92	Vidyarthyanchya Vidnyanav-ishayee Utsfurta Kalpana (Tech.)	5.00	Marathi		
93	Yuva Vidnyan Kutuhal	60	Marathi	2003	A. D. Ghaisas
94	Yuva Vidnyan Kutuhal	80	Marathi	2003	A. D. Ghaisas

Table E.8: Technical Reports.

S. No.	Title	Cost Rs.	Lang	Pub Year	Author
1	Talent Search & Nurture among Underprivileged	50	English	1985	V. G. Kulkarni, S. C. Agarkar
2	The Impact of Science Education	25	English	1987	V. G. Kulkarni, S. Chunawala
3	Children Talk About Motion		English	1989	J Ramadas
4	Comprehensive Prog to Improve the status of Science and Maths education in the tribal region of Mah.	25	English	1990	V. G. Kulkarni, S. C. Agarkar, V. G. Gambhir
5	Science Based Non-formal Edu.	54	English	1991	V. G. Kulkarni, J. Ramadas, S. P. Ozarkar, N. Bondale, V. G. Gambhir
6	Cognitive Studies at HBCSE, Technical Report No. 21		English	1993	J Ramadas
7	Comprehensive Quality Improvement Prog.	20	English	1994	V. G. Kulkarni, S. C. Agarkar, V. G. Gambhir
8	Remedial Programme in secondary schools in Tribal Ashram Shaalas	35	English	1995	V. G. Kulkarni, S. C. Agarkar, V. D. Lale
9	Tata Talent Search & Nurture: A Report	45	English	1995	C. Natarajan
10	Diagnosis Learning in Primary Science P-1		English	1996	S. Chunawala, C. Natarajan, S. Apte and J. Ramadas
11	Diagnosis Learning in Primary Science P-2		English	1996	C. Natarajan, S. Chunawala, S. Apte and J. Ramadas
12	Diagnosis Learning in Primary Science P-3		English	1996	J. Ramadas, S. Chunawala, C. Natarajan and S. Apte
13	Understanding Mechanisms of Normal and Abnormal Digestion, Technical Report No. 28		English	1996	J Ramadas and D. Ploger
14	Students Ideas about Science & Scientists.	97	English	1998	S. Chunawala, S. Ladage
15	Using Posters to Understand Students	180	English	2003	S. Mehrotra, R. Khunyakari, S. Chunawala, C. Natarajan
16	A Report of Project on OER for S (2007-13)	600	Eng/Mar	2013	
17	Tracking Gastro-intestinal Diseases	56	English		S. P. Rao D., B. S. Mahajan
18	Computer Literacy Methodology..	20	English		
19	Selected Papers of V.G. Kulkarni	50	English		V. G. Kulkarni

Table E.9: Conference Proceedings and epiSTEME Reviews

Sr. No.	Title	Cost Rs.	Language	Pub Year	Author
1	Proceedings of INDO-US Workshop	60	English	1992	Consolidated Report
2	epiSTEME - 1 Proceedings	175	English	2004	Consolidated Report
3	epiSTEME - 2 Proceedings	307	English	2007	C. Natarajan, B. Choksi
4	epiSTEME - 2 Reviews	750	English	2007	B. Choksi, C. Natarajan
5	epiSTEME - 3 Proceedings	995	English	2009	K. Subramaniam, A. Mazumdar
6	epiSTEME - 3 Reviews	1200	English	2009	K. Subramaniam
7	epiSTEME - 1 Reviews	350	English	2010	J. Ramadas, S. Chunawala
8	epiSTEME - 4 Proceedings	1500	English	2011	S. Chunawala, M Kharatmal
9	epiSTEME - 4 Proceedings in CD	100	English	2011	S. Chunawala, M Kharatmal
10	epiSTEME - 4 Reviews in CD	100	English	2013	Ed.: S. Chunawala and Meena Kharatmal
11	epiSTEME - 5 Proceedings	920	English	2013	G. Nagarjuna, A. Jamakhandi, E. Sam

Appendix F

India's performance at the Olympiads over the years

Table F.1: Yearwise performance in Astronomy Olympiads

Year	Venue	No. of Nations	No. of Indian participants	Gold	Silver	Bronze	Honourable mention
Astronomy							
2000 (IAO)	Russia	8	6	2	3	—	—
2001 (IAO)	Ukraine	7	6	2	2	1	—
2002 (IAO)	Russia	13	6	4	1	1	—
2003 (IAO)	Sweden	12	7	4	2	—	—
2004 (IAO)	Ukraine	19	5	4	—	1	—
2005 (IAO)	China	18	8	5	2	1	—
2006 (IAO)	India	19	8	5	1	1	—
2007 (IOAA)	Thailand	20	3	3	—	—	—
2007 (IAO)	Ukraine	20	6	3	2	1	—
2008 (IOAA)	Indonesia	21	5	2	2	1	—
2008 (IAO)	Italy	18	6	1	4	1	—
2009 (IOAA)	Iran	22	5	2	2	1	—
2009 (IAO)	China	16	6	5	1	—	—
2010 (IOAA)	China	24	5	3	—	2	—
2011 (IOAA)	Poland	26	5	3	1	1	—
2012 (IOAA)	Brazil	26	5	3	1	1	—
2013 (IOAA)	Greece	35	5	—	2	3	—

Table F.2: Yearwise performance in Biology, Chemistry and Junior Science Olympiads

Year	Venue	No. of Nations	No. of Indian participants	Gold	Silver	Bronze	Honourable mention
Biology							
2000	Turkey	38	4	—	1	3	—
2001	Belgium	38	4	1	3	—	—
2002	Latvia	40	4	—	3	1	—
2003	Belarus	41	4	1	2	1	—
2004	Australia	40	4	—	3	1	—
2005	China	50	4	1	—	3	—
2006	Argentina	48	4	—	3	1	—
2007	Canada	49	4	1	3	—	—
2008	India	55	4	1	2	1	—
2009	Japan	56	4	1	2	1	—
2010	Rep. of Korea	58	4	1	3	—	—
2011	Ch. Taipei	58	4	—	4	—	—
2012	Singapore	59	4	—	4	—	—
2013	Switzerland	62	4	—	3	1	—
Chemistry							
2000	Denmark	55	4	—	2	2	—
2001	India	60	4	1	3	—	—
2002	Netherlands	56	4	2	—	2	—
2003	Greece	60	4	2	2	—	—
2004	Germany	60	4	1	1	2	—
2005	Ch. Taipei	59	4	—	3	1	—
2006	Rep. of Korea	67	4	1	2	1	—
2007	Russia	68	4	2	1	1	—
2008	Hungary	66	4	—	3	1	—
2009	UK	64	4	—	4	—	—
2010	Japan	68	4	—	3	1	—
2011	Turkey	71	4	2	1	1	—
2012	USA	70	4	3	1	—	—
2013	Russia	73	4	2	2	—	—
Junior Science							
2007	Ch. Taipei	38	3	—	3	—	—
2008	Rep. of Korea	52	6	—	5	1	—
2009	Azerbaijan	46	6	1	5	—	—
2010	Nigeria	33	6	4	2	—	—
2011	South Africa	39	6	2	4	—	—
2012	Iran	29	6	—	6	—	—
2013	India	42	12	9	3	—	—

Table F.3: Yearwise performance in Mathematics and Physics Olympiads

Year	Venue	No. of Nations	No. of Indian participants	Gold	Silver	Bronze	Honourable mention
Mathematics							
2000	Rep. of Korea	82	6	—	5	1	—
2001	USA	83	6	2	2	2	—
2002	UK	84	6	1	3	2	—
2003	Japan	82	6	—	4	1	1
2004	Greece	85	6	—	4	2	0
2005	Mexico	85	6	—	1	1	3
2006	Slovenia	90	6	—	—	5	1
2007	Vietnam	93	6	—	3	—	3
2008	Spain	97	6	—	—	5	1
2009	Germany	104	6	—	3	2	1
2010	Kazakhstan	97	6	—	2	1	3
2011	Netherlands	101	6	1	1	2	2
2012	Argentina	100	6	2	3	—	1
2013	Colombia	97	6	—	2	3	—
Physics							
2000	UK	64	5	2	—	2	1
2001	Turkey	65	5	3	2	—	—
2002	Indonesia	67	5	1	4	—	—
2003	Ch. Taipei	54	5	2	—	1	2
2004	Rep. of Korea	71	5	1	2	2	—
2005	Spain	77	5	2	2	1	—
2006	Singapore	89	5	2	—	3	—
2007	Iran	70	5	2	2	—	1
2008	Vietnam	82	5	4	1	—	—
2009	Mexico	68	5	4	1	—	—
2010	Croatia	79	5	1	3	1	—
2011	Thailand	84	5	3	2	—	—
2012	Estonia	84	5	1	3	1	—
2013	Denmark	83	5	1	4	—	—

Appendix G

Criteria for faculty promotions

Draft criteria for promotion from Reader to Associate Professor, HBCSE

April 12, 2013

G.1 Broad categories

1. Publications in Journals and Conferences
2. Students Guided
3. Teaching including Project Work
4. Development of Educational Materials
5. Organization
6. Recognition in the Educational and Scientific Communities
7. Any other

G.2 Broad categories with sub-categories

1. Publications in Journals and Conferences.
   (a) Peer Reviewed Publications in Technical Journals
   (b) Conference Publications
2. Students Guided
   (a) Number of PhD Students Guided
   (b) Number of NIUS Students Guided
   (c) Number of PhD Students Co-Guided

   (d) Number of NIUS Students Co-Guided

3. Teaching including Project Work
   (a) Graduate School
   (b) NIUS
   (c) Olympiads
   (d) CBS, TISS other institutions
   (e) Students / Teacher Educator camps

4. Development of Educational Materials
   (a) Books (Olympiad, Curricular, Co-Curricular, Popular Science)
   (b) Lecture Notes (NIUS, Olympiad, for Teachers, for Teacher Educators)
   (c) Development of Assessment Resources (e.g. Olympiad, KVPY, CBSE Proficiency, NEST, NTSE, etc.)
   (d) Laboratory Development (for NIUS, Olympiad, others)
   (e) Software for Science Education and Popularization

   Documentation (in all cases) and evidence of usage (when possible) should be provided.

5. Organization
   (a) Olympiad exams (Indian National Olympiad Exams), camps and selection processes
   (b) NIUS camps and selection processes
   (c) Teacher education camps
   (d) HBCSE and related committees, Graduate test, JSO/JMO
   (e) Conferences, Seminars, Meetings in and on behalf of HBCSE

6. Recognition in the Educational and Scientific Communities
   (a) Plenary, Keynote and Invited talks at conferences and seminars
   (b) Serving on national and international bodies
   (c) Serving on editorial boards
   (d) Awards
   (e) Others

7. Any other

Appendix H

Centre for Learning Sciences

A preliminary proposal by Sanjay Chandrasekharan, Reader, HBCSE
for the TIFR Hyderabad Campus

HBCSE, the Science Education faculty of the TIFR Deemed University, is currently focused on research and development that seeks to redesign science education curricula, pedagogy and policy, such that:

1. teaching/learning of science and mathematics is more effective,
2. more students, particularly students from disadvantaged backgrounds, can learn these disciplines.

There are two rapidly developing trends in the science/education research interface that are critical to the further advancement of this research focus. These are:

- The emergence of the **Human Sciences**, particularly the cognitive and learning sciences, and the significant influence of the formal models developed in these disciplines on science and mathematics education.
- The development of **New Computational Media**, particularly model-based platforms for scientific discovery and learning, and the way these media are used to develop interventions for science and mathematics education.

These two research areas are closely related and highly interdisciplinary, combining science, engineering, social science and humanities perspectives. Apart from the scientific insight they provide into human-level systems, these emerging areas are of central interest to HBCSE because of the following reasons:

- They have seeded new learning approaches and technologies

- These (and other similar) interdisciplinary fields pose a challenge to education, as they deal with highly complex ideas and methods, and it is unclear how these could be systematized, such that these disciplines can be taught and learned effectively

- The new understanding of human behavior and human-level systems provided by these areas need to be made part of the school and college curricula, such that there is a beneficial impact on society (for instance, a better public understanding/acceptance of mental health issues and learning disabilities).

TIFR has very little presence in human sciences or new computational media. HBCSE is the only TIFR unit that is focused on studying human participants, as well as the role of representations/media in human activity. HBCSE is thus uniquely placed within the TIFR system to establish a research program in human sciences, combining these two important areas, but this requires a serious commitment from the TIFR Deemed University, particularly in integrating human sciences into its fundamental research mandate.

The following section outlines current HBCSE research in one of these areas (learning sciences), a related project with Indian Institute of Technology, Mumbai (IITB) to develop new computational media, and plans for further developing this research theme in the short and medium term.

H.1 Learning sciences

Learning sciences is an interdisciplinary field that seeks to develop explicit and formal models of the learning process in humans, particularly models of the cognitive, neural and physiological mechanisms involved in learning abstract concepts, such as numbers, fractions, area, mechanics, astronomy, DNA structure etc. Insights from these models and related experiments are then applied to develop new ways of teaching and learning complex concepts. A specific focus is the design and implementation of innovative digital media for learning science, mathematics and engineering. This new field brings together methods and perspectives from cognitive science, human-computer interaction, computer science, new media, anthropology, and recently, neuroscience.

This is a rapidly emerging research area, and many of the leading education research centres abroad have significant programs in learning sciences, as well as the new field of educational neuroscience. These include programs at Harvard University, Stanford University, Columbia University, Johns Hopkins University, Vanderbilt University, Cambridge University and University College, London (see Section H.3 for a more comprehensive list). There are many journals, Ph.D. programs and conferences focusing on the learning sciences (see Section H.4 for a list). The Fields Institute at the University of Toronto recently started a Cognitive Science network, for the empirical study of the cognitive nature of mathematics and how it is learned. On the technology front, building on the success of its *Foldit* video game (which allows novices to discover new protein folds), the University of Washington has started a Centre for Game Science, which focuses on developing new video games for science learning and discovery. Initiatives at the policy level include a funding program in the UK, where the government-backed Education Endowment Foundation and the *Wellcome Trust* has launched a £6 million scheme to fund neuroscience research into learning. Teachers in the UK are set to get training in neuroscience, with the teacher's union voting for such training. All these developments indicate that learning sciences is now a significant research area, and it will gain more prominence in the future.

HBCSE has done path-breaking research at the interface between cognition and education, particularly astronomy and biology education. However, learning sciences was not formally represented at HBCSE until recently, particularly the formal experimental component and the digital media component of learning sciences. The centre now has a learning sciences research (LSR) group, centred around a DST project in learning sciences, titled *The cognitive mechanisms underlying model-based discovery and learning*. This is a 3-year project awarded to the author under the Cognitive Science Research Initiative of the Department of Science and Technology of the Government of India (Category: Exploring Higher Mental Functions). It started in November 2013, with a budget outlay of 40.3 lakh (4.03 million) Indian rupees. The aim of the project is to develop novel experiments, methods and technologies to understand how students learn new concepts through the manipulation of external models (physical and computational) and artefacts. The focus of the project is understanding this process at the cognitive/neural mechanism level, particularly using eye-tracking. The project also seeks to develop a guiding framework for designing videogames and interfaces that support learning and discovery, based on the identified cognitive mechanisms.

The LSR group has a collaborative project with the Interdisciplinary Program in Educational Technology (IDP-ET) at IITB. The collaboration is expected to broaden rapidly through the recent resource-sharing MoU between HBCSE and IITB, which allows students from each institute to credit courses at the other institute. The MoU also allows joint thesis projects, where students can have co-guides at the other institute. The two Ph.D. programs complement each other well, with the IITB program focusing on applied issues such as digital media, technology and engineering education, and the HBCSE program focusing more on curriculum design, policy and theoretical frameworks.

Recently, the LSR group has developed a project with IDP-ET, where the focus is understanding how students learn to integrate different external representations, such as graphs, equations, and simulations. Using oscillation as an example concept, the project has developed a digital media system where the learner can manipulate any representation (graph, equation, simulation) and see the effect of this manipulation on the other two representations. Body-based interaction with equations and graphs is currently being implemented using the *Kinect* sensor.

In the short-term, the objective of this new media project is to establish a robust model for designing, testing and analysis of such interactions, and then scale it to many domains, such as chemistry, biology, mathematics, engineering and social sciences. Once enough of these interactions are available, they will be provided to teachers in a few seventh grade classes. Learners in these classes will interact with one such system every month in a year, and their science and mathematics performance will be tracked in grade 8 and 9, in comparison with control groups.

H.2 The way forward

To further develop HBCSE's presence in learning sciences in the short-term (3-5 years), one way forward would be to develop a joint Ph.D. program in this field with IIT-B, building on the synergy between the two Ph.D. programs, the institution-level MoU, and the already existing collaboration between the two groups. This program would be similar to other same-city joint Ph.D. programs worldwide (such as Harvard-MIT, Georgiatech-Emory, Duke-UNC etc.) and would require some strategic cooperation between the two institutions, particularly in hiring faculty. Since HBCSE, and TIFR in general, does not focus on digital media, design, human-computer interaction, and related issues, it would be difficult for us to hire faculty working in these areas. IITB would be more attractive for faculty with such backgrounds, because of related work done in IITB, particularly at the Industrial Design Centre (IDC). On the other hand, faculty with theoretical and experimental interests in learning sciences would find HBCSE more appealing, given the cluster of HBCSE faculty with related interests.

In the medium term (5-10 years), the research groups and programs that develop from this program could seed the core for a Human Sciences cluster at TIFR Hyderabad, focusing on Behavioural and Brain Sciences, particularly Human Learning. The learning areas represented in this cluster would be wider than learning sciences, and could include machine learning and robotics, neural plasticity and neural engineering, neuro-rehabilitation, and cross-disciplinary collaborations between these areas and the learning sciences.

In the longer term, this cluster could lead to engineering and technological developments that emerge from research problems in human learning. Understanding human learning requires developing new methods and technologies, some of which could develop from collaborations with other TIFR centres planned in the Hyderabad campus. For instance, the laser facility, and the Light theme in general, could help develop new human-level neuro-modulation techniques similar to optogenetics, and high resolution functional neuro-imaging based on near-infrared spectroscopy. This is just one example of the cross-fertilization that is possible.

H.3 Major research centres in learning sciences

- Carnegie Mellon University, USA
- CoCo – Centre for Computer Supported-learning and Cognition, The University of Sydney

- LinCS – The Linnaeus Centre for Research on Learning, Interaction and Mediated Communication in Contemporary Society, The University of Gothenburg, Sweden
- Center for Learning and Knowledge Technologies, CeLeKT, Växjö University, Sweden
- Centre for Learning Sciences and Technologies, Open University of the Netherlands, The Netherlands
- Learning Research and Development Center – University of Pittsburgh, USA
- Learning Sciences Institute - Arizona State University, USA
- Learning Sciences Research Institute – University of Illinois at Chicago, USA
- Learning Sciences Research Institute – University of Nottingham, UK
- LIFE (Learning in Informal and Formal Environments) Science of Learning Center, USA
- Learning Sciences Lab, National Institute of Education, Nanyang Technological University, Singapore
- Pittsburgh Science of Learning Center, USA
- Spatial Intelligence and Learning Center (SILC), Northwestern University, USA
- Munich Center of the Learning Sciences (MCLS), Ludwig-Maxmilians University, Munich, Germany
- Knowledge Media research Centre, Tuebingen, Germany
- Educational Science and Technology, University of Twente, Enschede, The Netherlands

H.3.1 Joint programs in neuroscience and learning sciences

- Mind, Brain, and Education program, Harvard University, USA
- Educational Neuroscience program, Stanford University, USA
- Educational Neuroscience program, Vanderbilt University, USA
- Centre for Neuroscience in Education, Cambridge University, USA
- Science of Learning Institute, Johns Hopkins University, USA
- Neuroscience and Education, Teacher's College, Columbia University, USA
- Southwest Center for Mind, Brain and Education: UTA, Texas, USA
- Centre for Educational Neuroscience, University College London, UK
- Neuroeducational Research Network: Bristol, UK
- National Key Laboratory of Cognitive Neuroscience and Learning, Beijing Normal University, China

H.4 Journals, graduate programs and conferences

H.4.1 Associations and journals

- Cognition and Instruction
- Instructional Science, An International Journal of the Learning Sciences
- International Society of the Learning Sciences
- The Journal of the Learning Sciences
- The International Journal of Computer-Supported Collaborative Learning
- Mind, Brain & Education Journal
- Neuroeducation
- Trends in Neuroscience and Education

H.4.2 Graduate programs specializing in the learning sciences

- Arizona State University, Learning Sciences Institute, USA
- Carnegie Mellon University's PIER, HCII, METALS, USA
- Georgia Institute of Technology, USA
- Indiana University, USA
- Ludwig Maximilian University of Munich, Psychology Master's Program in the Learning Sciences
- Ludwig Maximilian University of Munich, Doctoral Training Program
- McGill University, Canada
- National University of Ireland, Galway
- New York University, USA
- Northwestern University, USA, Masters and Ph.D. in Learning Sciences
- Open University of the Netherlands, MSc Programme Learning Sciences
- Pennsylvania State University, USA
- Rutgers University, USA
- Stanford University, USA
- Teachers College, Columbia University, USA

- Tufts University-Department of Education, USA
- University of California, Berkeley, USA
- University of California, Davis, USA
- University of California, Los Angeles, USA
- University of Colorado Boulder, USA
- University of Illinois, Chicago, USA
- University of Malaysia Sarawak, UNIMAS, Malaysia
- University of Memphis, USA
- University of Michigan, USA – Learning Technologies
- University of Minnesota, USA
- University of North Carolina-Chapel Hill, USA
- University of Nottingham, United Kingdom
- University of Pennsylvania, USA
- University of Pittsburgh, USA – Learning Sciences and Policy Program
- University of Sydney – Master of Learning Science and Technology Program
- University of Washington, Seattle, USA – Learning Sciences Graduate Program
- University of Wisconsin, Madison, USA
- Utah State University, USA
- Vanderbilt University, USA
- Virginia Tech, USA
- Worcester Polytechnic University, USA

H.4.3 Conferences and organisations

EARLI Special Interest Group (SIG) on Neuroscience & Education: The SIG brings together researchers from the fields of educational research, cognitive (and developmental) psychology and (cognitive) neuroscience as well as interdisciplinary people with training in each of these fields, all of which investigate human learning and development. Taking interdisciplinarity as a basic principle, the SIG conceives the relation between educational research and neuroscience as a two-way street with rich bi-directional and reciprocal interactions between educational research and (cognitive) neuroscience.

Brain, Neuroscience and Education: A Special interest group of the American Education Research Association (AERA)

International Mind, Brain, and Education Society: The mission of the International Mind, Brain, and Education Society (IMBES) is to facilitate cross-cultural collaboration in biology, education and the cognitive and developmental sciences.

Learning & the Brain Conference: Learning & the Brain provides educational Conferences, Symposiums and Summer Institutes and professional development on the latest research in neuroscience and psychology and their potential applications to education.

The London School – Neuroeducation Centre

Appendix I

HBCSE staff list

I.1 Permanent staff

Table I.1: Academic staff.

S.No.	Name	S.No.	Name
1.	Jayashree Ramadas	10.	Gadiraju Nagarjuna
2.	Vijay A. Singh	11.	Krishna Kumar Mishra
3.	Chitra Natarajan	12.	Jyotsna Vijapurkar
4.	Belur J. Venkatachala	13.	Rajesh B. Khaparde
5.	Sugra Chunawala	14.	Aniket Sule
6.	K. Subramaniam	15.	Paresh K. Joshi
7.	Savita Ladage	16.	Prithwijit De
8.	Rekha Vartak	17.	Karen Haydock
9.	Anwesh Mazumdar	18.	Sanjay Chandrasekharan

Table I.2: Scientific staff.

S.No.	Name	S.No.	Name
1.	Narendra Deshmukh	10.	T. Sandhya Rajshekhar
2.	Vijay Lale	11.	Prakash Nawale
3.	Vinod Kumar Sonawane	12.	Manoj K. R.
4.	Shirish Pathare	13.	Shweta Naik
5.	Anand Ghaisas	14.	Pravin Pathak
6.	Swapna Narvekar	15.	Indrani Das
7.	Anupama Ronad	16.	Rupesh Nichat
8.	Meena Kharatmal	17.	Anil Sankhwar
9.	Dinesh Pednekar	18.	Vikrant Ghanekar

Table I.3: Administrative staff.

S.No.	Name	S.No.	Name
1.	Madhavi Gaitonde	11.	Rashmi Shrotri
2.	Vijay Raul	12.	Devendra Mhapsekar
3.	P. K. Balakrishnan (Consultant)	13.	Swapnila Desai
4.	Medha Mastakar	14.	Milind Shinde
5.	Sumana Amin	15.	Gauri Tawate
6.	Manisha Deshmukh	16.	Hemant Mandlik
7.	Smita Burli	17.	Tilottama Shirodkar
8.	Mahesh Bamne	18.	Ravindra Sawant
9.	Manish Thakur	19.	Snehal Sawant
10.	Santosh Rasam		

Table I.4: Technical and Auxiliary staff.

Technical Staff			
S.No.	Name	S.No.	Name
1.	Nanasaheb Tribhuwan	5.	Vijay Ahire
2.	Sudhir Pardeshi	6.	Karun Hambir
3.	V. C. Jacob	7.	Sachin Chavan
4.	Hindurao H. Rane		
Auxiliary Staff			
1.	Jagdish B. Waghmare	6.	Nivruti Thigale
2.	Umesh Shenoy	7.	Gajanan Mestry
3.	Ravindra More	8.	Jaywant Tambe
4.	Nivruti Kadam	9.	Bhaurao Bhagit
5.	Bhimsingh Valvi		

I.2 Temporary staff

Post-doctoral Fellows: Post-doctoral fellowships encourage those who wish to pursue a career in STME to spend a year or two contributing to the Centre's ongoing R&D projects. Dr. Arvind Jamakhandi is a post-doctoral fellow.

Project staff: Project staff, about 55 at any time, assist in a variety of projects at the Centre. Current designations of project staff at HBCSE are the following:

- Project Scientific Officer (B)
- Project Assistants
- Project Tradesman
- Project Work Assistant

Table I.5: Current Ph.D. students of HBCSE.

S.No.	Name	Year of Joining
1.	Ruchi S. Kumar	2006
2.	Amit Dhakulkar	2006
3.	Aisha M. Kawalkar	2006
4.	Arindam Bose	2007
5.	Aswathy Raveendran	2007
6.	Saurav Shome	2007
7.	Amit Sharma	2008
	Research Scholars	
8.	Anveshna Srivastava	2009
9.	Jeenath Rahaman	2009
10.	Shikha Takker	2009
11.	Shraddha Ghumre	2009
12.	Rafikh R. Shaikh	2010
13.	Prajakt P. Pande	2010
14.	Rosemary Varkey M.	2011
15.	Gurinder Singh	2011
16.	B. J. Rama Rao	2012
17.	Himanshu S. Srivastava	2012
18.	Geetanjali R. Date	2012
19.	Rossi D'Souza	2012
20.	Durgaprasad Karnam	2014
21.	Subhayan Kabir	2014
22.	Deborah Dutta	2014
23.	Kanchan Mishra	2014

Appendix J

HBCSE Mangement Board and HBCSE Committee

Table J.1: HBCSE Management Board

Prof. M. Barma, Director, TIFR	Chair
Prof. J. Ramadas, Centre Director, HBCSE	Convener
Prof. E. Krishnakumar, DNAP, TIFR	
Prof. M. K. Mathew, NCBS	
Prof. N. Mukunda, IAS, Bangalore	
Prof. Chitra Natarajan, Dean HBCSE Faculty	Member-Secretary
Prof. Jaikumar Radhakrishnan, STCS, TIFR	
Prof. Parvin Sinclair, Director, NCERT	
Prof. Vijay Singh, National Co-ordinator, Science Olympiads	
Wg. Cdr. George Antony, Registrar, TIFR	

Note: Constituted w.e.f. August, 2012

Table J.2: HBCSE Committee

1.	Prof. Jayashree Ramadas	Centre Director and Chair
2.	Dr. Sanjay Chandrasekharan	
3.	Prof. Sugra I. Chunawala	
4.	Dr. Prithwijit De	
5.	Dr. Karen Haydock	
6.	Dr. Paresh K. Joshi	
7.	Dr. Rajesh B. Khaparde	
8.	Prof. Savita A. Ladage	
9.	Prof. Anwesh Mazumdar	
10.	Dr. K. K. Mishra	
11.	Dr. G. Nagarjuna	
12.	Prof. Chitra Natarajan	Dean, HBCSE Faculty
13.	Prof. Vijay Singh	
14.	Prof. K. Subramaniam	Member Secretary
15.	Dr. Aniket P. Sule	
16.	Prof. Rekha R. Vartak	
17.	Prof. B. J. Venkatachala	
18.	Dr. Jyotsna Vijapurkar	
19.	Prof. R. S. Bhalerao	TIFR Colaba
20.	Prof. Arnab Bhattacharya	TIFR Colaba
21.	Prof. Vandana S. Nanal	TIFR Colaba

Appendix K

Comments by Prof. N. Mukunda

K.1 Comments on October 17, 2013

Prof. Mukunda's remarks during the meeting of the HBCSE faculty with the Management Board held at HBCSE on October 17, 2013.

1. The review is delayed but welcome. You need to be very critical in your review.
2. The Olympiad and NIUS programmes require enormous efforts and take up much of the resources of the centre. You need to ask questions about these programs.
3. Thirty years ago did the Centre think of this (Olympiads and NIUS), or did these priorities/goals come from outside?
4. As far as the Olympiad programme goes, you need to do it, no one else can do it. So you cannot stop. But you need to recognize how it became your responsibility.
5. The burden of the Olympiad programme has come rather by default, but the NIUS programme is born from an idea within the Centre. There is a difference.
6. You have been helping various institutions. For example, you have helped KVPY, NISER, CBS, with their entrance exams. Should HBCSE offer to do this? In the US there is a separate organization for this function – the Educational Testing Service. You need not expend energy on this if there are more important things that you should be doing.
7. The USSR managed to achieve physics education of a high quality across many institutions in a short time. How did it achieve this?
8. Teaching is important. The best textbooks are written by teachers. For example, Griffiths was a teacher in a small college.
9. I liked all the sentences on page 55 of the review document[1]. It says here that HBCSE should seed capability in other institutions rather than take on things

[1] Draft document of October 17, 2013

itself. I agree with that. You need to generate ideas, to think about how ideas can be generated, how they can be tested, and how to take it outside HBCSE. And you need to do this.

10. There are about 25000 colleges in the country where science is taught. Maybe there are about 50 colleges which are good. Can you make this a few hundred colleges? Your ideas should be implemented in at least a few hundred colleges. [Making a model of] five to six colleges is too small for this Centre.

11. As for schools, there are about 500,000 schools, about 100,000 at the senior secondary level. I don't have any understanding of how to influence such a vast system.

12. You are stuck at the moment with olympiads. To make a difference (in Olympiads, at school level, undergraduate level?), you need a faculty strength of 35-40. You can also start looking beyond a single Government Department like Atomic Energy.

13. For your review, you can call eminent persons from within the country. You don't necessarily need to get persons from abroad.

14. If you can convince them (review experts) of your vision, I don't see why it is impossible to get enough faculty positions.

K.2 Comments on August 5, 2014

Of the many Centres of TIFR - including NCRA, NCBS, ...- HBCSE has quite unique features that set it apart from the rest. I see its work as made up of at least three basic components: specific programmes it has undertaken on its own to serve the needs of the country, such as the Olympiads and the NIUS; interaction with and contributions to the educational system of the country at various levels from school to college; active research of its faculty in the field of science education leading to peer reviewed publications in good quality journals. I am sure the members of the Review Committee will be given full information on all these aspects. The Committee will hopefully give broad guidelines on how to distribute the intellectual and other resources of the Centre among these areas.

In the matter of assessment of individual faculty, it may be good to expect that each one contributes to say two out of the three areas, possibly at least one in a major way. The Committee's views on this, and on the balance between working as individuals and as members of a team, would be valuable.

Equally useful would be its advice on the kinds of work the Centre should offer to undertake in future in response to requests from other bodies and agencies. I think it is important to gradually build up a strong image and reputation for specific kinds of work which help define the character of the Centre, and therefore be selective in what is undertaken in helping others. For advice on this I think the views of the Committee members from within the country would be particularly valuable as they would be familiar with the conditions in which the Centre functions.

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