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## Innovative Pedagogy in Transforming Science Education

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*A growing revolution is under way in the teaching of science to undergraduates. It is driven by concerns about Indian competitiveness as well as results from recent educational research, which explains why traditional teaching approaches in large classes fail to reach many students and provides a basis for designing improved methods of instruction. Discipline-based educational research in the life sciences and other areas has identified several innovative promising practices and demonstrated their effectiveness for increasing student learning. Innovation pedagogy is "a learning approach focused on the development of innovation competences, defining how knowledge is assimilated, produced and used in a manner that can create innovations". Innovation competences are learning outcomes that refer to knowledge, skills and attitudes needed for the innovation activities to be successful. The humanistic way of understanding people as the creators of their own future forms the philosophical foundations of innovation pedagogy.*

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### Introduction

The concept of innovation pedagogy is a didactic operational model based on the socio-cultural perception of learning that supports the work of universities of applied sciences as a part of regional competence and innovation networks. Applied research and development activities that support regional development and the production of innovations in working life are integrated into multidisciplinary teaching in accordance with the principles of innovation pedagogy. The education offered by the university promotes entrepreneurship and includes service activities while taking into account both the needs of the region as a whole as well as the constantly changing trends of working life.

Learning environments where students of different fields are daily in contact with each other offer new interfaces for working. Such surroundings are known to be best when innovations are expected. In addition, an innovative approach to teaching and learning are also needed as well as enthusiasm for trying new methods. In the context of innovation pedagogy, innovations are seen as an integral part of the process of constantly improving know-how as well as generating new

sustainable ideas and practices applicable in working life. A fruitful environment for innovation consists of individuals with different backgrounds working together on similar problems. These innovation communities can be tight teams meeting every day or network-like looser communities. The success of the communities is based on know-how and sharing knowledge as well as on the ability to combine different points of view and approaches. Innovations are more frequently generated where different fields of expertise meet.

Thus, the aim of innovation pedagogy confesses the societal needs as the basis for the work done at HEIs. Having social learning theories as a background, innovation pedagogy links university work together with the regional needs emphasising the meaning of innovation competencies without forgetting the study specific skills students must have. Innovation pedagogy emphasises the meaning of teamwork and multidisciplinary groups, as well as internationalisation as main sources of innovations and especially as core competencies which a today's innovator should have. Innovation pedagogy is put into practice via different activating learning methods such as hatchery methods that produce study specific and innovation competencies, and simultaneously serve regional, national and international operators ensuring direct societal benefits.

#### Various Types of Innovative Pedagogy

- Sensitization of Parents and Community
- Organized visits to Science Museums, Innovation hubs and Science fairs and Mathematics Melas
- Participation of Students in Inter-school, State/ National Science and Mathematics competitions/ Olympiads etc.
- Expand outreach of programmes of Ministry of Science and Technology to promote science learning
- Science, Mathematics and Technology Clubs for Children
- Promotion of Science & Mathematics Teacher Circles
- School Mentoring
- Effective Classroom transaction: teaching –learning
- Strengthening teacher support institutions through use of technology
- Development of Resource Materials
- Use of Technology in Science and Mathematics teaching
- Provision of Teaching-learning equipment and materials
- Strengthening School Science and Mathematics Laboratories
- Recruitment of Science and Mathematics Teachers
- Assessment Design for Science and Mathematics for students
- Teacher Preparation for Science, Mathematics and Technology

#### Sensitization of Parents and Community

Government will contribute to nurture SMT talent among children through right attitudes through following activities viz.,

- Promotional communication strategy to sensitize parents and society on Science and Mathematics education in an increasingly knowledge-based society through mass media.

- Community-Scientist interactions at six monthly intervals using TV, Radio and other technologies.
- Engagement of parents in Classroom teaching at school level.
- Invitation of parents and community leaders in Science and Mathematics events/ activities of schools
- Parent-Science & Math teacher meetings
- Engage Civil Society / NGOs working on Science and Mathematics (selected based on set norms by State/ National level Mentoring Institution) in popularizing science and mathematics.

#### Organized Visits to Science Museums, Innovation Hubs and Science Fairs and Mathematics Melas

- Guided student visits to local vocations/ activities involving traditional and modern science and technology viz., Cycle / Car / Road Transport/Rail/Ship yard workshop, Dairy, agriculture, field irrigation system, Bakery, community radio/ TV station, zoo, power stations, telephone exchanges etc.; and Science Museums/ Parks/ R&D centres/ Institutions of /Higher Education/ Industry etc.
- Planned visits to Science Museums and Innovation hubs under mentorship of Higher Education Institutions/ UG or PG Students of Engineering or Science / Mathematics students.
- Visits to Science fairs and Mathematics Melas organized locally

#### Participation of Students in Inter-School, State/ National Science and Mathematics Competitions/ Olympiads etc.

- Under schemes of the MHRD, schools, students would be encouraged to participate in programmes and events that promote Mathematics and Science awards and incentives for children. The effort would be to take these programmes/events to decentralized levels to ensure greater wider participation and involvement of teachers and children as well as ensure greater & wider participation of children in competitions and awards.
- MHRD, NCSM, Nehru Yuvak Kendras & DST will work together to encourage following greater participation of children in the events:

#### Events

- National Children Science Congress
- Teachers Science Congress
- Competitions for Science & Innovation at State/district level
- Maths and Science Olympiads
- IRIS Intel Programme
- ISRO Science Competitions
- Citizen Science Programme
- MHRD, NCSM, DST (VP) & Nehru Yuvak Kendras would also collectively work for the following
- Formation of Science Clubs in all Schools in phases, in partnership with Vigyan Prasar.

- Subscription/ Membership in Science Clubs/ Circles
- Encouraging students to write Science communication articles in local media based on self- observation, experience and analysis.

### Expand Outreach of Programmes of Ministry of Science and Technology to Promote Science Learning

Expand outreach of programmes of Ministry of Science and Technology and National Council of Science Museums (NCSM) for school children, to cover schools across the country and for wider participation of children. The schemes of MHRD, SSA and RMSA would enhance the outreach of DST and NCSM programmes to all Govt. Upper Primary Schools and all Govt. & aided Secondary schools as per approved norms.

- DST's Scheme for Early Attraction of Talents for Science (INSPIRE) involving identification of students of classes 6-10 of age group 10-15 years, for INSPIRE awards to seed and experience the joy of innovation with Rs.5000/ per child (one time grant) would be popularized across schools to enable greater participation from all schools.
- INSPIRE Internship School camp for the top 1% students in Class X examination of all School boards would also be popularized and all secondary schools encouraged to participate and compete.
- NCSM Innovation hubs will be actively involved in student engagement and long-term handholding.

### Science, Mathematics and Technology Clubs for Children

MHRD in partnership with Vigyan Prasar (DST) and National Council of Science Museums (NCSM) will assist schools in a nationwide effort to institutionalize science clubs for students in schools for Science and Mathematics. Mentoring Institutions will play a lead role in formation of these clubs. Science based reputed voluntary agencies could also be involved at local level to provide necessary support to building activities of Science Clubs and popularize them in schools amongst children and local communities. The objectives of the Science & Mathematics clubs would be to:

- Stimulate a spirit of curiosity, enquiry, innovation and creativity amongst students/children through activities which would supplement conventional (in class) education and make science and mathematics an enjoyable and interesting pursuit.
- Motivate children and youth to take up scientific activities and contribute towards the cherished goals of achieving a scientific society.
- To transform teachers as a facilitator and change agent (from that of educator)
- To encourage and empower students to participate in the National Children's Science Congress.

Informal out-of-school engagement with Science and Maths Teachers would typically be learner-motivated, guided by learner interests, be voluntary, contextually relevant, collaborative, nonlinear, and as often open-ended. The activities to be undertaken under the RAA, thus would have to be:

- Designed to be interactive, support and encourage learners to extend their learning over time
- Provide multiple ways for learners to engage with concepts, practices, and phenomena within a particular setting
- Promote and support participants to interpret their learning experiences in the light of relevant prior knowledge, experiences and interests
- Developed through partnerships with appropriate expert(s)/ agencies and wherever possible be rooted in scientific problems and ideas that are relevant for the local community.
- All educational tools and materials should be developed through iterative processes involving learners, educators, designers, and experts in SMT through appropriate field trials.

### Promotion of Science & Mathematics Teacher Circles

- Teachers of Science and Mathematics in Schools to be grouped by Mentoring Institutions in teacher circles at decentralized levels on a voluntary basis. The Mentor Institutions would endeavour to develop teacher capacities for teaching Science and Mathematics in new and empowering ways so as to render the experience of Science & Maths teaching in an engaging manner for children.
- Mentoring Institutions would try to engage teachers as a community, with the depths and intricacies of specific subject details (Science and Mathematics) to propagate a culture of doing and creating knowledge through problem-solving, 12 programme and demonstration.
- The Monitoring Institutions would try and propagate a culture of “beyond text books” to bring live Science, Mathematics and Technology issues in to the classroom.
- The MIs would help to provide a platform (at decentralized levels) for teachers to share experiences with each other, make & present presentations of them professional experiences – innovations, successes and failures in teaching-learning of Mathematics and Science with their peers.

The MIs would provide expert mentoring and build partnerships in these meetings. The MIs would help form & sustain Teacher Circles that can be

- Subject oriented Circles
- Project-based clubs/Circles
- Problem-solving circles
- Guided exploration circles
- Research mathematicians/Scientists
- Topic-centred clubs
- Applied math /technology clubs

Teacher Circles/ Clubs in Science and Mathematics would encourage local school-based programs, development of low cost Science and Mathematics kits for schools to use, local campaigns on natural events/phenomenon in Science, residential summer programs for teachers for up-gradation in Science and Mathematics teaching, methods, organize local Math/Science

contests for students and teachers or both, teaching Workshops/Seminars/Demonstrations on fun with mathematics/science lessons, organization of local Science Exhibitions/Book fairs/Math Melas, publish media articles on Science & Mathematics, activities on Contemporary scientific events to create awareness etc.

- Provision of Good books for teachers in different languages and e-format.
- Subscription/ Membership to local, regional, State and National Teacher Science & Mathematics Associations/ Circles/ National Teachers Science Congress (NTSC).
- Participation in National Teachers Science Congress and activities of nearby Research /R&D Institutions/Mentoring Institutions.

### School Mentoring

Higher Education Institutions (HEI) will be encouraged and networked to mentor neighbourhood Higher Secondary, Secondary and Upper Primary schools over a period of 5 years. They will be called Mentoring Institutions' Bhabha Centre for Science Education (HBCSE), Indian Institutes of Technology (IITs), Indian Institute of Science Education and Research (IISERs), National Institutes of Technology (NITs), National Council of Science Museums (NCSM) and other institutions would provide the leadership and engage with mentoring of schools.

The Department of Science and Technology and National Council of Science Museums (NCSM) through its various agencies would also play a major role in mentoring and encouraging activities in schools for the promotion of science. The students of Indian Institutes of Technology /NIT and other premier Institutions may be encouraged to mentor KVS & NVS school students to take up local problem-solving projects. For the purpose the State/UT Govt. will map schools and Higher Education Institutions and then network each other considering neighborhood, mutual convenience and subject interests etc. The role of these Mentoring Institutions would be to:

- To improve student engagements through Science and Mathematics activities in schools
- To create a culture of “making and doing” by students and teachers. To encourage collaborative engagement of teachers and students with planned and coordinated sustenance in the form of material access (resources, documentation and e-materials), institutional support (work load, scheduling, flexibility etc.) and intellectual support (content experts, mentoring, etc.).
- To ensure technology enabled scientific talks at schools.

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 Effective Classroom Transaction: Teaching –Learning

Endeavour is for an enabling Class room transaction with following features viz.

Sustained & Active engagement with every child	Hands on-Activity based learning	Problem Solving
Experimentation & Demonstration	Modelling	Self- Learning
Peer-to-Peer Collaborative Learning	Online resources	Culture of Beyond Text books and inquiry-based learning

### Sustained & Active engagement with every Child

- Teaching –learning preferably be in the mother tongue of children /child’s home language/language of school instruction related to daily life experience and socio-cultural context, especially in case of primary classes.
- Encouraging children to share their experiences, news and observations in nature in the class and use their talk as a resource in building classroom discussion richer.
- Allow children to invent their own ways of using existing vocabulary to convey science and mathematical ideas.
- Encourage children to express their scientific and mathematical findings.
- Opportunity to respond, discuss and share STM readings and books.
- Encouraging children to participate in classroom activities through asking questions and framing of problems.
- An environment that tolerates learning from failures and therefore motivates children (and teachers) to be creative, and think out-of-the-box.
- Encouragement for perseverance, by providing positive reinforcement for persevering on tasks; and by not rewarding only the fastest correct answer.
- Hands on-Activity based learning
- Problem Solving
- Modelling
- Experimentation & Demonstration
- Self-learning
- Peer to peer collaborative learning
- Online resources (in local language) use
- Culture of Beyond Text books and inquiry-based learning.

### Strengthening Teacher Support Institutions through use of Technology

The State SCERT/SIE, IASE, CTE, DIETs and Block and Cluster Resource Centres be strengthened with specific emphasis on Science and Mathematics by constituting a Resource Group at each level and build their capacity by networking them with Higher Education Institutions, Teacher Circles and Science Congress etc. The teacher educators and academic

support institutions (SCERT, DIETs, BRC and CRCs) also be empowered in using ICT in science and mathematics teaching-learning and activities.

### Development of Resource Materials

MHRD will constitute an Institutional consortium under the joint leadership of NCERT, DST and National Council of Science Museums (NCSM) to undertake the following activities viz.,

- NCERT in collaboration with DST Vigyan Prasar, National Children Science Congress and National Science Teachers Congress will systematize availability of academic resources on Science & Mathematics in the country.
- The online resources available at NCERT NROER (National Repository of Open Educational Resources) will be further improved with the collaboration of Children's Science Centre, Pune, UNESCO, Home Bhabha Centre for Science Education and other organizations working for promoting science math teacher education in the country.
- NCERT, National Book Trust, Vigyan Prasar, Bal Bhawans, National Computer Saksharta Mission, Sahitya Academy, National Council for Science & Technology Communication and other institutions be encouraged to make available their publications in e-format in the public domain.
- NCSTC, NCERT and National Book Trust to translate popular science books available in public domain in different scheduled regional languages.
- Individual authors be invited to contribute e-Books.

### Use of Technology in Science and Mathematics Teaching

The Higher Secondary, Secondary and Upper Primary Schools will incrementally be supported with ICT infrastructure to support Science and Mathematics teaching/learning in order to transform the scope of classrooms to e-classrooms, rich in audio-video, demonstrations and access to internet.

### Provision of Teaching-Learning Equipment and Materials

Good scaffolding and other conceptual, physical demonstrations, mathematical and statistical visualization and digital models which fosters active engagement of children in the classrooms be encouraged. All schools be provided with a variety of science and mathematics models and science magazine for example (National Institute of Science Communication and Information Resources) for active engagement of children. In addition, School libraries be enriched with books for teachers and students to sustain interest in Science, Mathematics and Technology.

### Strengthening School Science and Mathematics Laboratories

School Science Laboratories will be strengthened based on set standards. The students will be given opportunity to explore and visualize science and mathematics ideas, concepts through activities and enhance their understanding of the subjects through critical thinking and problem-solving skills. All the elementary and secondary Schools will be provided Science and Mathematics Kits to augment materials for use in mathematics to understand concepts as well as to build upon understanding for applications and problem solving. Funds under centrally

sponsored schemes can be accessed for the purpose. Mentoring Institutions can help & guide schools/States Govt. to build appropriate & modern school laboratories.

#### Recruitment of Science and Mathematics Teachers

- States and UTs must have earmarked teacher posts for Science and Mathematics from classes VI to XII and recruitments be done with teachers with Science and Mathematics background as per NCTE guidelines Regular monitoring of States/UTs for filling up of vacancies.
- States Governments & Universities to keep register of Science & Maths graduates and organize regular counselling services to attract such graduates to Teacher Professional Degrees/Diplomas such as D.Ed. & B.Ed. etc.

#### Assessment Design for Science and Mathematics for Students

- Development of appropriate methods for Continuous and Comprehensive Assessment learning of Science & Mathematics by teachers, where in students are assessed not for rote learning of Science and Mathematics concepts but by testing their comprehension through applications and projects, problem solving and creative use of concepts etc.
- Workshops & seminars to be held with school boards to rectify assessment systems. Mentoring Institutions Science/ Maths organizations, Department of Science & Technology and National Council of Science Museums (NCSM) to play a lead role in this task.

#### Teacher Preparation for Science, Mathematics and Technology

##### Pre-Service Teacher Education

Review of Teacher Education Programmes curriculum (viz., D.El.Ed., B.Ed. etc.) on Science, Mathematics and Technology with emphasis on problem solving, critical thinking, and reflective learning and on incorporating the use of technology in Science and Mathematics teaching-learning, pedagogy and assessment systems.

##### Teacher in-Service Capacity building

- Enlist best and brightest teachers in Science and Mathematics in the State/ UT as Master Teachers for developing training designs and training modules for Science and Mathematics separately for primary and upper primary, secondary and senior secondary levels. Teacher training modules to promote spirit of enquiry, discovery, project work and investigation, validation and application of concepts in day-to-day life of a child.
- Capacity building of Teacher Educators in SCERT, CTEs & IASEs, DIETS & Block and Cluster Resource Centres on the design, modules and conduct of In-service teacher training in Science and Mathematics.

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## Mentoring System

Teacher Mentoring by Science, Math Teacher based Higher Education Institutions/ R&D Institutions/Private S&T Institutions. Basic guidelines for mentoring by Higher Education Institutions & SC/Maths organizations to include: -

- Support – material (print, ICT-NROER, lab resources, space, maps), institutional (policy, network, scheduling), and intellectual (subject experts, college teachers, researchers) are provided with resource material viz. Posters, Audio-visual material, visually rich handbooks, pamphlets, videos etc. to facilitate conceptual understanding of different aspects.
- Block/Cluster level Meetings with Teacher SMT Circle members and for Peer learning. Peer discussion to include teaching processes, children learning behaviour, their interests, and their resources and ways in which these can be brought into the classroom for improved learning outcomes.
- Demonstration, practice and reflection opportunity for Teacher to observe, learn and space for making and doing and get opportunity for classroom and beyond classroom practice under guidance in pedagogy & methodology sensitive to the diversity of learners and learning situations.

### Academic Support

Access to Resource Persons (BRP/CRP) for guidance and feedback and innovation.

### National Teachers Science Congress (NTSC)

Encourage and support teachers to communicate and share innovative concepts/methodologies in the fora. Mentoring Institutions to help identify and nurture Science & Maths teachers towards this goal.

### Teacher's as Change Agents

Orientation of School Head Masters and Teachers to nurture student Science and Mathematics clubs/ circles as motivators (not as Educators) to create excitement and stimulation for SM&T among students/children.

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