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Science Education

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SCIENCE AND SCIENCE EDUCATION

In India, as in the West there have been attempts at changing both the nature and practice of science as well as the teaching of science as part of general education. The nature of science refers to the epistemology of science. Lederman defines the nature of science as "the values and assumptions inherent to science" (Lederman, 1992) and states that there exists a range of meanings to describe this complex human endeavour.

The efforts at reforming science teaching have often been too restricted in scope and have focused mainly on updating the science content in textbooks. Most science educators do agree that students must develop an understanding of the nature of science. However, even among science educators there is no consensus about the nature of science. In this context, there is a need for a philosophy of science education but it appears to be far from being formulated.

WHY TEACH SCIENCE?

In the absence of a comprehensive philosophy of science education, the question that most needs an answer is "what is the justification for teaching science and technology in our schools?" Is it to have an educated citizenship or to provide adequately prepared and motivated students to fulfil the industrial needs of the country? Is scientific literacy one of the goals of science education? If it is, who can be considered scientifically literate? According to one definition, a scientifically literate individual is "one who makes informed decisions within a science and technology context by drawing upon their rich scientific knowledge, such as, an understanding of the concepts, principles, theories and processes of science" (Abd-El-Khalick et al., 1998). Many science educators view the achievement of scientific literacy as the educational solution to the varied economic, social and environmental challenges of the 21st century.

It is becoming clear that teaching science has no single unambiguous aim. Different groups in society view the aims of science education differently. Some see the aims in vocational terms (providing skilled work force); others perceive educational goals, in developing the individual potential of the child. The production of highly qualified scientists and engineers is a valued objective, while another is to produce educated citizens. There is no shortage of statements of aims, but the translation of these aims into measurable objectives results in the loss of important aspects and reduces science education to trivialities (Woolnough, 1989).

CONTENT AND PEDAGOGY IN SCIENCE

In general terms science education can be said to include the following aims; to impart information and provide a context for theory, train the powers of observation, memory, expression, skills of reasoning and logical investigation. This is because the notion of questioning, investigating the question, and communicating the results are often defined as important aspects of the scientific enterprise and of the nature of science itself.

However, there is more to learning science than gaining knowledge and developing skills.

The area of the affective, the personal acceptance and enjoyment of and commitment to the scientific activity is of central importance in doing science. Doing science is a holistic activity involving the will and the imagination as well as the hand and the mind.

In India, as in several countries, learning science is not as popular as it should be. Too few students choose to continue with science into higher education and to a career. Science in schools is often criticised for being too prescribed, impersonal, lacking in opportunity for personal judgements and creativity. Science has reduced to a series of small, apparently trivial activities and pieces of knowledge unrelated to the world in which students are growing up.

There is a growing acceptance among science education reformers that the processes of doing science should not be separated from scientific content and that the aims of science education should be clearly spelt out.

CLASSROOM TRANSACTION OF SCIENCE

Learning science is never only about learning to know the natural world. Students also learn how the social world is perceived. Science education necessarily contains values. Science has to be recontextualised in order to be meaningful in school. Science education practices have a potential for socialising students. From a cultural perspective, students with different world-views may attend classes wherein the context of science may be in conflict with their backgrounds.

Students entering the science classroom have a number of previous experiences, ideas, beliefs and expectations about the natural world. The content taught in the classroom is interpreted in the light of this prior knowledge. Even after formal instruction, students' spontaneous conceptions often remain at variance with accepted scientific ideas. These have been labelled alternative conceptions. Research all over the world has gone into uncovering alternative conceptions in different groups of students, and drawing their implications for learning.

It is fairly well recognised now that alternative conceptions cannot be easily replaced by correct scientific ideas. One way of looking at this resistance is to imagine that students'conceptions form an interconnected system of beliefs: about the nature of science, of school, of learning, and of the world around. Any one of these beliefs cannot simply be treated as a scientifically inaccurate idea that is easily corrected. That idea has to be understood in terms of a more general world-view held by the student, and it has to be also tackled from that perspective (Ramadas, 1993).

Knowledge is constructed through interaction with the physical as well as the social environment. Alternative conceptions, therefore, need to be seen in terms of the context of learning, including the socio-cultural and linguistic background of students, and its relation to the classroom climate.

PAST TREND REPORTS

The earlier reviews of researches in science education (Ganguli and Vashista, 1991) and (Vaidya, 1997) reported that only a few studies were conducted in the field of science education. Ganguli and Vashista listed a total of 101 studies during the period of the first four surveys in educational research. The first four surveys covered a period of 14 years from 1974 to 1988. This would suggest around seven studies per year.

Vaidya reported a total of 61 studies during the period covered by the fifth survey (1988-1992). The annual average (number of studies by number of years) increased from 7 to 12 from the period of the fourth to the fifth survey.

The areas where the research was concentrated in the period of the fifth survey were:

- Environmental studies
- Curriculum, syllabus and textbook
- Learning science and models of teaching
- Teaching strategies
- Outcomes of science education (scientific temper, attitudes, skills and interests)
- Correlates of achievements in science
- Educational Technology
- Other studies

According to the review by Vaidya (1997), the research frontiers that needed to be traversed were, history and philosophy of science and policy studies in science education.

PRESENT SURVEY OF EDUCATIONAL RESEARCHES IN SCIENCE EDUCATION (1993-2000)

In the present survey, a total of 120 researches in the field of science education could be recorded. The sources covered by this survey were: *Indian Educational Abstracts, International Journal of Science Education, Resonance, Journal of Research in Science Teaching and the Journal of Education and Social Change.*

It appears that the number of studies uncovered in a period of eight years still appears small. The total number of studies uncovered for this period has almost doubled (from 61 to 120) and the annual average has increased from 12 to 15. Yet, the final tally of 120 studies is miniscule and does not reflect favourably on the existing and increasing growth in the number of schools, colleges, universities and institutions along with the large number of persons, in the form of teachers, lecturers, readers, professors, teacher-educators, full-scale researchers and other academic staff who are involved in science education.

The generation of research, the areas that dominate it and the academic levels at which these works are carried out, could give us some insight into the academic involvement in science education. The Table 1 indicates one possible categorisation of the researches conducted in the period.

ACADEMIC LEVELS AT WHICH THE RESEARCH WAS CONDUCTED

Table 2, presents a classification of the studies in the survey period by the levels at which they were conducted. The table indicates that none of the studies were conducted as an M.Phil study, while 12% were doctoral studies. Three per cent of all the studies were conducted as Independent projects, while eight per cent of the studies were NCERT/SCERT publications. A considerable majority of all these studies, 77% were research papers.

Thus, research papers form the bulk of the studies during the survey period. The lack of M.Phil studies in comparison to doctoral studies suggests that M.Phil perhaps is not seen as a suitable avenue for studies in science education. At the same time, it is interesting that doctoral studies which formed a bulk of the fifth survey have also decreased as compared to research papers. The trend appears to be for researchers

Table 1: A possible categorisation of the various studies in science education

FREQUENCY OF STUDIES IN VARIOUS AREAS OF SCIENCE EDUCATION		
Areas of Science Education	*No. of Studies*	*(%)*
Students' attitudes towards science	13	11
Cognitive studies of science	39	32
Teaching material	18	15
Science teaching	23	19
Environmental factors	7	6
Achievement of students in science subjects	6	5
Creativity	3	3
Gender issues in science teaching	6	5
Miscellaneous	5	4
TOTAL	**120**	**100**

Table 2: The different academic levels at which the studies were conducted

Levels of Research	*No. of Studies*	*(%)*
M. Philosophy theses	0	0
Doctor of Philosophy theses	14	12
Research Papers	92	77
Independent Projects/Studies reports	4	3
NCERT/SCERT Publications	10	8
TOTAL	**120**	**100**

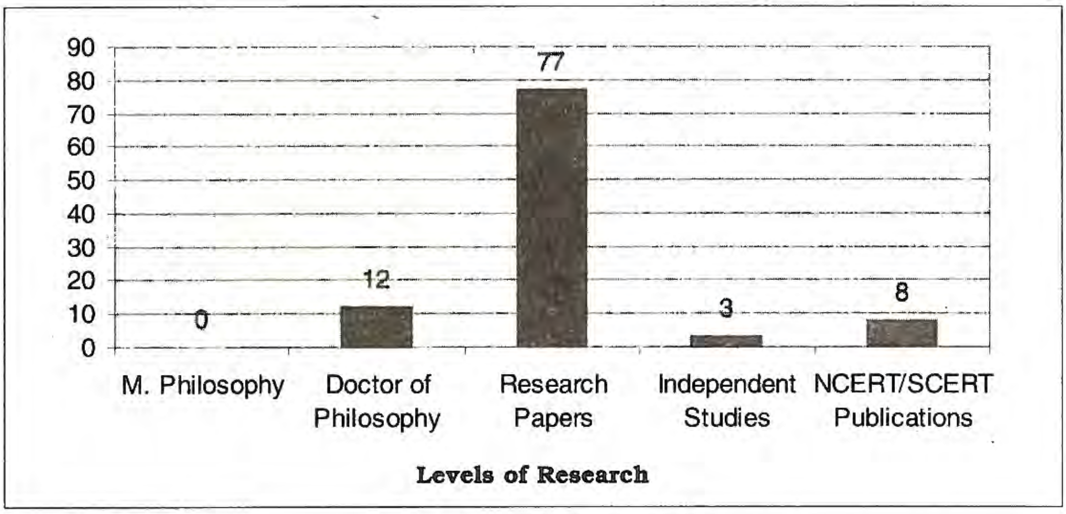

Fig. 1: Levels of Research

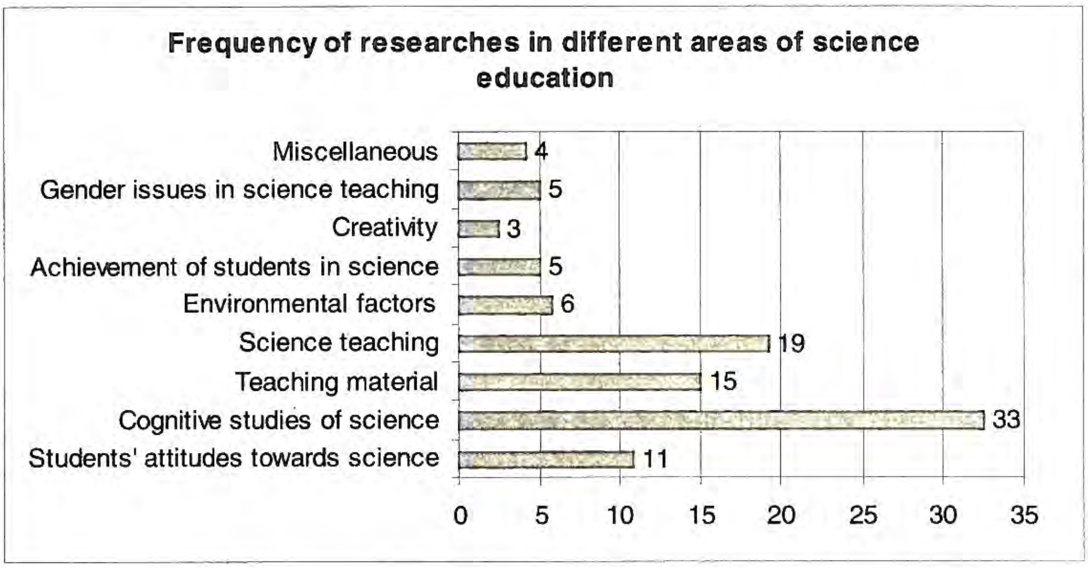

Fig. 2: Studies in different areas of science education

rather than students to be conducting research studies and publishing them in this period.

The lack of communication between researchers and practitioners may explain why research does not inform practice in education. One way to breach this gulf is by involving teachers and students in the research process. Collaborative action research would also make it easier to implement educational reforms.

COGNITIVE STUDIES

A major area of research in science education the world over is cognitive studies. A glance at Fig. 2, indicates that a majority of the studies could be placed in the area of cognitive studies in science (32%). Cognitive research aims at developing a "science of science learning". The underlying theoretical notions about knowledge, thought and learning are drawn from cognitive science, which is an interdisciplinary field, deriving inputs from psychology, neuroscience, linguistics, information processing and education. The cognitive science paradigm in education is at present the most dominant one, and in Kuhnian terms has been fruitful in terms of opening up areas for research. While this paradigm is generating a lot of research in the area of students' understanding of science, its translation into actual classroom practice has been limited.

The Swiss psychologist, Jean Piaget proposed that children construct their mental structures, through interaction with their environment, and that all children pass through a set of invariant stages of cognitive development. His ideas led to work in education aimed at matching the cognitive demands of curricula and the students' stage of development. Later works have indicated that learning is more complex and that cognitive factors may be domain-specific, that is, not easily generalisable.

A large number of studies in this category had focused on "understanding of science," "misconceptions of science" and "cognition". Some studies focused on what it is that students understand of the science that is taught to them. Studies on understanding of science often compare the material available in the texts and the teaching of some aspects to the ideas that students carry away. An example of one such study is; Mahajan, B.S. and Chunawala, S. (1999), "Indian secondary students' understanding of different aspects of health". The study conducted on students from different socio-economic backgrounds, reported that students had a poor understanding of nutritional, social and genetic factors associated with health.

Various researchers have conducted a number of studies on students' misconceptions or alternative conceptions held by students in different subject areas. There is some disapproval of the terms "misconceptions" and "alternative conceptions" and thus, the term 'spontaneous conceptions' are more often used. An example of a study on misconceptions in biology at the high school level is Ansari, A.B. (1998), "A study of misconceptions concerning genetics and evolution in biology at high school level in relation to formal reasoning ability, cognitive style and achievement". The study reported that performance on achievement was inversely related to the number of misconceptions held by IX Standard students studying biology in two government schools of Bhopal.

Physics has been the focus of a large number of such studies as in, Kumar, A. (1994), "Students' cognitive frameworks in physics", and in Saxena, A.B. (1994), "Identification of misconceptions related to work and energy among students". Errors in chemistry were also extensively reported in this survey. Some of the studies focusing on chemistry were, Gupta, V. P. (1997), "A comparative study of the performance of students at +2 stage in chemistry-Isomerism in carbon compounds", Vidyapati, T.J. and Radhakrishna, P.M. (1993), "Chemical calculations involving the mole", and Douglas, S.P. and Rao, G.S. (1997), "A diagnostic study of the common errors committed by students in writing and solving of chemical equations".

Both teachers and students were the focii in different studies. However, teachers were less often studied as compared to students. Some of the studies were: Saxena, A.B. (1995), "A study of teachers' alternative frameworks in physics" and Kishore, L. and Sharma, R.K. (1997), "A study of primary teachers' responses to assess their understanding of competency-based environmental studies curriculum subsequent to participative training programme". While it may be difficult, there is a need for studies to include teachers' ideas and concepts as part of their work.

Cognitive studies to a large extent focused on secondary and higher secondary students' conceptions. Some such studies were, the work of Panse, S.; Ramadas, J. and Kumar, A. (1994) on "Alternative conceptions in Galilean relativity (I): Frames of reference", and Singh, S. (1998), "Analysis of common errors in chemistry at +2 level".

Few studies focused on elementary students' conceptions. Pachaury, A.C. (1994), studied "Disadvantaged elementary school children: their concept of death and its causes". Another study with primary school students conducted by Mohapatra, J.K. and Das, S. (1996), was titled "Classroom processes leading to connotative relativity: A generative cause of primary level pupil's alternative conceptions".

The influence of Piaget on the Indian educational and research scene is undeniable and most of the studies had a constructivist base. A few studies explicitly referred to Piaget in the title of the paper, such as the paper by Rajgopalan, M. (1995), "An investigation of Piaget's formal reasoning in science among a section of Indian school students". This study had the objective of preparing a paper and pencil type test of formal reasoning in science that would be suitable to Indian pupils. The test that was devised was found to be useful in identifying formal reasoning at five levels. Another related study was Mohapatra, J.K. and Mohapatra, M. (1998), "Are the science reasoning tasks good discriminators of the Piagetian stages? -A study under Indian conditions".

Thus, it appears that in the Indian scenario as in the West, cognitive studies form a core research area in education that can have a significant impact on curriculum development and practice.

SCIENCE TEACHING

This was the second largest focus of research (18%) during the period of the survey. The role of the teacher is to facilitate school learning. This role of a teacher in science has taken on newer dimensions and added complexity with the introduction of technology as an addition to science education.

Some of the different studies in science teaching during the period of the survey had focused on how to better teach some specific content or subject matter to be taught. The work by Jadhao, V.G. and Parida, B.K. (1996), titled, "Teaching of force, work and energy at the lower primary level", attempted to review the use of these concepts in the NCERT textbooks and reported that teaching of these concepts as delineated in the books would lead to the development of misconceptions among students.

Other studies focused on the lessons that could be learned when focussing on teaching some specific content. Saxena, A.B. (1996), in his work "Lessons from teaching shadow and eclipses in a primary school" aimed at identifying the difficulties faced by teachers and at suggesting effective teaching methods. The activity approach using locally available materials was found to increase the achievement levels of students substantially

The context of teaching was often the subject of research, such as, teaching in large or rural classrooms. Agarkar, S.C. (1997), "Programme to improve teaching of science and mathematics in rural secondary schools", and Kaushal, A.K. (1997), "Science teaching in large classrooms: A comparative study of the effectiveness in selected primary schools of the National Capital Region" are examples of studies focussing on the differing contexts of teaching.

Research studies also focused on the assessment or development of skills in students, such as, Bhattacharya, G.C. and Choudhari R. (1993), "Major biology teaching skills and their identification", and Swamy, A.M.A. (1995), "Effect of inquiry training model of teaching science on science process skills, creativity and curiosity of secondary school students", Unpublished doctoral dissertation, Karnataka University.

The use of various strategies in teaching to benefit learning, were the subject of some studies. Banerjee, A. (1997), compared the effect of lecture and co-operative learning strategies on achievement in chemistry in under-graduate students. Peer tutoring was a strategy reported on, by Gyanani, T.C. and Pahuja, P. (1996). The paper reported that peer tutoring was highly effective in developing the spatial ability of students, and more so in the case of low achievers and learning disabled students. Reddy, G.L. and Ramar, R. (1997), also focused on slow learners and use of multimedia in their paper "Effectiveness of multimedia instructional strategy in teaching science to slow learners".

Teacher education was the subject of a few studies, such as the work of Masih, A. (1997), on "Restructuring the B.Ed. course for teaching integrated science teachers: A proposal", and Masih, A. (1998), "Preparing integrated science teachers for general education: A proposal". Agarkar, S.C. (1998), focused on in-service training, while a totally different aspects of teachers and teaching was elaborated by Mohapatra, J.K. (1998), in his work titled "Are teachers teaching EVS-II at the primary level competent enough? An in-depth study".

Ethics and values in and through science teaching was an area of study. Dhanasekaran, S. and Gunasekaran, S. (1995), studied the place of ethics in social science and science teaching in Tamil Nadu. Amalraj, A. (1999) undertook a study to learn if the physics content of science textbooks for Classes VI to VII, promotes values. The study reported that the values promoted were, Intellectual values (such as Creativity) and Personal values (such as, cleanliness, time alertness). However, the textbooks did not promote Social values (such as, Punctuality, Co-operation), Economic values (such as, Saving, Budgeting) and Aesthetic values (such as, symmetry, and beauty).

TEACHING MATERIALS

The preparation of teaching materials was another important area in which research was conducted and reported (13%). These teaching materials encompassed a range from development of curriculum to science kits and software development as well as analysis of the various media in which these materials are to be presented.

Curriculum design was an area of interest for some researchers. Maharjan, S.D. (1995), (unpublished doctoral dissertation) attempted to develop an environmental studies science curriculum for primary schools of Nepal. The development and assessment of teaching programmes of various kinds was another major educational research activity. Some programmes were aimed at improving students' attitudes to science. Vidhate, S.N. (1997), prepared a teaching programme for developing scientific attitudes (unpublished doctoral dissertation), while others were aimed at teachers, Patnaik, S.P. and Basavayya, D. (1997), "Development of training package in Environmental Studies II for primary teacher trainers".

Some studies emphasised developmental aspects of new materials. Patel, V.G. (1995), studied the role of network analysis of the biology syllabus of Standard XI. The investigator found that teaching biology through networks was better than teaching through traditional methods. Testing and trials of the new materials was often an integral aspect of the development of materials, such as, in the papers by Joshi, A. and Mahapatra, B.C. (1997), "Effectiveness of computer software in terms of reasoning ability in science", and Puri, H.S. (1993), "Developing and using an inexpensive science kit for elementary students". The major outcomes of this work were that the kit developed was self-instructional and the activities developed by the kit were based on the syllabi of grade II to V. These activities were easily adaptable for rural and urban situations and used readily available and inexpensive material.

The relation between the prepared material and students' achievement was explored by Kulkarni, B.B. (1997), in his paper titled, "A study of the effect on pupil achievement caused due to the use of teacher's handbook, as teaching aid". The print media was the focus of some studies. Chand, R. (1998) attempted to ascertain the pattern of reading science based articles by students and teachers at the secondary level. The study reported that students taught through science news based articles did improve their performance academically. Purundare, V. analysed the utility of various aspects of science textbooks, such as diagrams, writing in bold, and others for facilitating science learning. In her work (1997), she reported that these aspects were found useful by students, teachers and parents who made use of the textbooks at home.

Thus, the two categories, science teaching and teaching materials (development and testing) accounted for one third (31%) of all studies in the period of this survey.

ATTITUDES AND SCIENCE

Attitudes appeared to be a continuing field of interest (11%) for studies in science education. The development of better attitudes towards science is often recognised as an important aspect of science education, and research into students' images of science has been around for quite some time. Chambers (1983) states that in the eighteenth and nineteenth centuries, there were varied visual and verbal images of scientists, which are rarely seen now. Though these images were stereotypic, their range was large, varying from scientists as diabolical madmen to harmless eccentrics. However, as science transformed its organisational structure, improved its general social status, and established its social authority, a new professional image emerged in the media, which is a 'cleaned up' and standardised one. How do students view science and scientists? And is this perception important to science educators in any way?

A study by Khatoon, T. (1998), was aimed at relating students' attitudes to science and achievement, "Minority students' attitude towards science and their achievement:

A comparative study". Other studies focused on the changes or differences in students' attitudes to science as a consequence of education. Bagchi, J.P. (1993-94), studied the impact of different educational practices on students' attitudes towards science, while Maitra, K. and Maitra, A. (1997), focused on a specific aspects of science, that is, exploring students' attitudes towards laboratories and other related practical work in science.

Jayasree, K's (1998) doctoral dissertation was an attempt at correlating scientific attitude and attitude towards science. Another doctoral work by Patil, G.S. (1997), was a study of scientific attitude of secondary school students from a rural area. The construction of a standardised scale for the measurement of scientific attitude was a part of the thesis. Scientific attitude was related to students' performance by Paulose, P.J. (1995), "The influence of scientific attitude of university entrants on their process outcomes in physics". The attitudes of teachers were the focus of study by Naik, A.K. and Pathy, M.K. (1997), "A study of the attitudes of secondary school science teachers towards teaching of science".

Attempts were made in a few studies to identify the factors related to attitudes and science such as; the doctoral works by Rani, S.D. (1997) "A study of problems of science education and attitude of students towards science in high schools of East Khasi Hills district, Meghalaya". Sandhu, R.C. (1998) tried to ascertain the school and non-school factors as determinants of attitude towards science. A standard measure of scientific temper, was developed by Sharma, P. and Shukla, P. (1999) "CSAT as a diagnostic measure of scientific temper".

GENDER ISSUES IN SCIENCE EDUCATION

Gender issues in science education appeared to be an emerging branch of study. Six per cent of all the studies could be classified as having gender as an important variable. This is a significant departure from the earlier surveys and reflects a worldwide trend. In the field of education, gender issues are important and have relevance for research and policy implementation. What is the relation of gender to science learning? One major gender issue in this field is the under-representation of women and girls in science. Women are not only less likely to choose to study science or to choose a scientific career than men, but within science classes, they are less active than men (Jones and Wheatley, 1988).

This under-representation of women is often 'explained' by suggesting that there are biological differences in cognitive ability between men and women. The issue of sex differences in learning falls into the classic argument of nature versus nurture. Research in this area has been by and large inconclusive. The differences, if any, in ability, turn up only at ages when it is difficult to separate the effects of genetic factors from socialisation. There may or may not be biological explanations for sex differences in learning but it is obvious that sociological factors play an important role. From the earliest possible stage, girls and boys are treated differently by those close to them, differing expectations are held from them and later, the mass-media constantly bombards them with messages of what it is to be male or female in the society.

The studies in the survey have tried to capture these differences that females face in science education. Sobha, I., Rammohan V. and Reddy, M.S.N. (1995), have studied the problems faced by girl students in women's polytechnic, Pillai, K.S. and Usha, P. (1994) have studied the effects of parent's sex bias in education on achievement in physical science of secondary school pupils. The study reported that the achievement in physics varied according to the sex of the pupils and also according to parents' sex bias or unbiased perception of education. There was only a slight difference in mean achievement scores of unbiased boys and girls. But the scores of biased boys and girls varied to a great extent. The variation in the achievement scores of boys and girls was due to their parent's sex bias in education.

Some studies tried to uncover whether males and females have different cognitive styles, Durga, T. K. (1993) or whether they have differing interests, Nayak, R.S. (1996). Kishore, L, (1998) made an attempt at understanding the issue of relationship among gender, science, technology and mathematics, while Pillai, K.S. and Kumar, P.K.S. (1994) have tried to correlate achievement in Biology with sex, locale, cognitive style and approaches to studying.

CREATIVITY

Research in the area of creativity had been quite productive and the earlier surveys had a large number of studies based on creativity in science education. However, during the period of this survey few studies concentrated on creativity. Only three studies could be placed under this category. These studies either focused on cognition and achievement such as, the study by, Nanda, A. and Pal, G. Ch (1994), or on cognitive preference styles in a particular subject, such as, the paper by Rajyalakshmi, T. (1996) on "Creativity and cognitive preference styles in biology". Pachaury, A.C. (1997), aimed at uncovering the perceptions of Indian scientists regarding creative students. The study focused on the characteristics of creativity in students endorsed by scientists and compared these to the perceptions of experts in the field of creative personality. No difference was found in the perception of scientist and experts in creativity regarding the characteristics of creative students. Some of the traits common to both and ranked most desirable were: Curious, Courageous in convictions, Independent in judgement, and preoccupied with tasks. Traits ranked by both the groups as least desirable in students were: timidity and haughtiness.

ACHIEVEMENT IN SCIENCE

Students' achievement in science was studied by relating it to various factors. One such factor to which students' achievements were related was the teaching or teaching material. Bagchi, J. P. (1993), studied the efficacy of different biological science curricula at the senior secondary level on the basis of attainment in learning outcomes of students. The effectiveness of mastery learning strategies across socio-economic levels in terms of VIII Standard students' chemistry achievement and modification in their self-concept was provided by Deshpande, S. and Bhat, S.G. (1994).

Padhi, J.S. (1996), studied the effect of a competency-based, activity-centred approach to teaching on attainment of mastery level learning in environmental studies. The study found that such a teaching approach was more effective than a traditional approach for students studying in Grade I. A doctoral dissertation by Salim Kumar, C. (1994) on the interaction of approaches to studying and achievement motivation on achievement in biology of secondary school pupils found that variation in achievement in biology was not dependent achievement motivation.

A study by Lalitha, P.R. and Rao, N.R.N. (1996) was an exception. It studied the vocabulary required by Class III students to achieve mastery in EVS II as per the Minimum Levels of Learning (MLL's). This study reported that students having a good vocabulary did well on EVS.

ENVIRONMENTAL FACTORS

There were a limited number of studies on the various environmental factors in or out of class that are relevant to learning in science. There were three papers by Padhi, J.S. from 1993-1994 on this topic, of which two explored the home environment and its effects on pupil's academic self-concept and achievement in science. The other paper attempted to study the effect of the socio-psychological environment of the family on academic self-concept and achievement in science of junior secondary school students. The study found that the homes of high academic self-concept students were controlled, permissive, socially isolated, and less permissive whereas the homes of high achievers were also controlled, protective, punishing, less nurturing and less permissive.

Other papers looked for non-cognitive predictors of scientific knowledge (Kundu, R.; Chakraborti, P.K. and Ghosh, P., 1994). Two doctoral dissertations also presented other factors related to science achievement. The work of Santha Kumari, K.M., 1998, was aimed at studying the influences of the classroom climate on achievement in physics of secondary school pupils. The study noted that classroom climate had a significant effect on achievement of physics. Usha, P., 1992 studied certain socio-familial correlates of secondary school science achievement and found that the educational and occupational levels of parents (both father and mother) were significantly associated with achievement in the physical sciences. She also found that pupils of parents who showed less sex biases attained higher scores in the tests of achievement.

MISCELLANEOUS

This category contained studies that could not be placed under the other categories. Of the five papers that fell in this category, several were interdisciplinary in scope and content. An example is a study by Gupta, H.O. and Singh Anupama (1994) on the "Status of science teaching in Indian schools for the visually impaired". The study reported that the present status of science teaching for the visually handicapped is quite poor because of lack of specially trained teachers and suitable equipment and instructional material.

Another paper comparing the "Teaching aptitude of Science and non-Science student teachers in relation to their level of anxiety", by Bhattacharya, G.C. (1995), fell in this category as well as a paper by Banerjee, A.C. (1994) on "Reforms in science education in the context of education for all". The relation of research in science to science education was presented by Varma, R.K. (1998), in an article in the journal *Resonance.*

THE WAY FORWARD

What are the directions that science education research will take and what are the less explored areas that need further work in? As stated earlier, Vaidya in his review had clarified that the research frontiers that needed to be traversed were, history and philosophy of science and policy studies in science education. These areas are still the boundaries that need to be breached.

The historical approach in science education views science as a social endeavour, humanises it and projects it as dynamic enterprise expanding in scope and depth with time. This approach in the curriculum makes pedagogic contributions by generating interest, creating motivation, inculcating values of equity and anti-authoritarianism and projecting science as a multi-cultural and international enterprise. The fields of history of science, philosophy of science and sociology of science are deeply intertwined and in the science curriculum would present not only science but also its very methodology as evolving with time. The need to develop curricula, teaching materials with these perspectives in mind and to assess the presence of these perspectives in the existing teaching materials and curricula would be as imperative as evaluating such material and studying the relation of these materials to other cognitive and attitudinal aspects.

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