THE ECONOMIC TIMES

FIRST PRINCIPLES

A monthly column on Education

Jayashree Ramadas
Homi Bhabha Centre for Science Education

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Contents

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JAYASHREE RAMADAS

Let's play ball with the moon

Why do we get a stomach upset? I asked twelve year old Ajit. "It is because of germs". He answered casually, "we have learnt about that in science". "Really? Where do these germs come from, and what do they actually do in your stomach?" "When we eat too many sweets, they rot inside the stomach and make tiny germs. The germs eat all the food in our stomach and grow bigger and bigger, they turn into worms and bite us from inside." "Did your teacher tell you this?" "Not all of it," said Ajit, "but I have seen pictures of germs in a book, so I know it is true."

Traditional methods of teaching rely on a view of the learner which dates back to Plato – a blank slate which can be written on by experiences. The teacher's job, according to this view, is to present the content so that it can be recorded on memory faithfully. Sometimes there may be loss in transmission, or the recording may get fainter with time, but if the teachers' presentation is clear and forceful, the intended message will get across.

A few innovative teachers may sometimes use hands-on experience in science, relying on field trips, activities and even discovery methods. Despite their value, such methods often fail to address the basic issue: is the message going across to students? How much do they really understand?

Most good teachers realize that students are often unclear on basic concepts. The best students in the class might do well on text book science questions, but they usually can not apply their knowledge to real situations. In mathematics, students may acquire calculation skills, but rarely develop problem solving abilities.

Research over the last 20 years has challenged the simple model of the learner as a blank slate and questioned the present teaching methods. The student entering the classroom comes with a host of experiences, ideas, beliefs and expectations about the natural world. What is taught is never recorded faithfully nor simply overwritten on previous preconceptions. The student 'interprets' the new content in the context of his or her prior knowledge. This view of learning implies an active construction of knowledge inside the student's head. New knowledge cannot be simply absorbed.

It has to be assimilated and in the process, existing knowledge also needs to be restructured.

Very young children are astonishingly fast learners. In a year or two from birth they pick up complex knowledge that allows them to talk fluently, deal with the physical world, with people around them, and to get things done in their own way. They do like this any good scientist would: by constantly forming hypothesis, testing them against experiences, modifying them when necessary, and incorporating the results in their theories about the world. By the time students formally start learning science, their naïve theories ('alternative conceptions') are already quite extensive.

These naïve theories persist if teaching fails to take account of them. The student has a vague sense of unease, of not really understanding science, and not being able to identify the exact problem.

There are several ways in which the student resolves the issue. Sometimes, new ideas are simply rejected for being inconsistent with earlier ideas. More often, naïve theories coexist with the science taught in the classroom, with a tacit understanding that school science is for the exams, while 'commonsense' is for dealing with the real world. Sometimes, as in the case of Ajit quoted above, ideas learnt in school are integrated with preconceptions to form a composite theory, in which science is clearly mis-interpreted.

Systematic research is being done in countries around the world to understand students' naïve theories in different areas of science. This has been an active area in The Homi Bhabha Centre for Science Education in Bombay, dealing till now with the topics of light, motion, Galilean relativity, chemical combinations and human physiology. We have seen, for example, on the subject of light that students may learn about rays of light going in straight lines, but in everyday contexts they may still think of light as a diffuse substance that stays around the light bulbs, that illuminates objects from a distance, that helps you to see things when it enters your eyes from a source and goes from your eyes to the object.

With these insights into learning, the teacher's job becomes more complex. She has to understand the preconceptions of students, invent appropriate examples and learning activities that will challenge the students' ideas, help them understand the legitimate contexts in which their own ideas have been formed, and make the scientific notions intelligible and plausible.

Fortunately it may not be necessary to understand individually the naïve theories of some 50-odd students in the classroom. That would be a near impossible task. Human beings have common ways of reasoning and experiences of the natural world are also common across the children. Some interpretations which come from everyday language may also fairly universal due to common roots of Indian languages. If at the start, the teacher gets students to make their spontaneous ideas explicit, to make them aware that there are other ways of thinking, to get them discuss and defend a set of ideas against a competing one, a beginning would have been made.

The whole exercise has to be carried out in such away that the students feel that their ideas are important and valued in the classroom. That would require a radical change from the authoritarian atmosphere of our classrooms. More importantly, the syllabus load will have to be drastically reduced if genuine understanding is to get priority. This is where curriculum makers and textbook writers come into picture. They have to incorporate new ideas about learning into textbooks so that the teachers' load is reduced. —

The author is with the Homi Bhabha Centre for Science Education, Bombay. This column will appear once a month.

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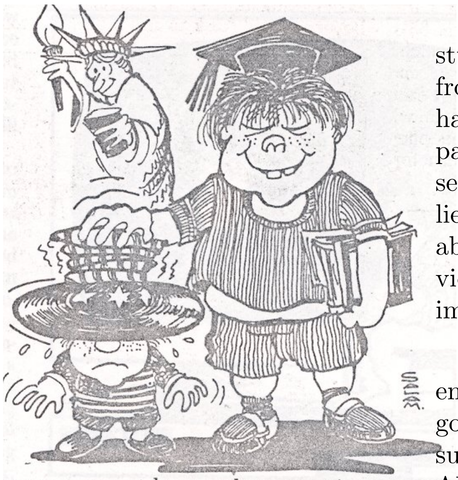
JAYASHREE RAMADAS

The burden of shibboleths



American educators have been disturbed by a series of cross-national survey of educational attainment. These tests have shown, year after year and beyond doubt, that students in Japan, China, Taiwan, Korea and even Indochinese refugee families out-perform American students in Maths, science and reading: Not just in basic skills but in creativity and problem-solving tests also.

Researchers have looked at the possible factors behind this success. Much to everyone's relief, the answer does not seem to lie in intelligence differences or inherent ability but with certain attitudes towards education and schooling. Chinese and Japanese students, and also their parents, consider education to be crucial to success in life. Indochinese refugee families in America place great value on reading and learning.

Japanese, Chinese and Indochinese students (I will call them "Asian" from now on) are willing to work harder than their American counterparts. One reason for their motivation seems to be their and their parents' belief that effort is more important than ability. Thus, they de-emphasise individual differences in potential, and give importance to hard work.

American students and their parents have wide-ranging and diffuse goals, consisting of material and social success (not necessarily via education). Also, they believe in innate ability, and thus do not see the relevance of extra effort.

Perhaps the extraordinary performance of Asian students carries a high psychological cost. Are they straining under the enormous pressure to succeed? Is this strain leading to high rate of suicide, to incidents of cruel ragging in schools?

The answers are not as clear-cut as often made out in the media. The adolescent suicude rate in Japan decreased by 43 per cent during 1975-84, while it increased in US by 17 per cent. Comparative studies of psychological adjustment in Asian and American students find that the latter show more evidence of stress, academic anxiety, and aggression. The clear academic goals of Asian students, along with the whole-hearted support of their parents and teachers, may in fact reduce the strain of hard work.

Whatever the verdict, this controversy should not detract from the lessons that we need to learn from our neighbors, from their parents as well as from their school systems. We have two separate systems of schools: the government or municipal schools catering to students fro lower socio-economic backgrounds, and better-off private schools. The problems in these two types of schools may appear to be different, but at another level, they both have to do with attitudes.

I have spoken to students, teachers and parents belonging to the first kind, the rural and municipal schools. Quite often, I have found a fatalistic attitude towards the performance of students who come from poor families, have no guidance at home and are sometimes suspected of having low intelligence. The baseless ness of such beliefs has been demonstrated repeatedly in a few exceptional schools around the country and in research projects at the Homi Bhabha Centre for Science Education.

Yet we do not seem to realize the enormity of loss to the country by our lack of will to invest in education. By lack of commitment, we fail to draw the best out of the vest pool of talent which stagnates in our forgotten villages. In a recent book called *The Child and the Sate in India*, Mr. Myron Weiner claims that it is not so much poverty, but the negative attitudes of our educators and officials which are at the root of our slow progress towards universal primary education. We even have influential politicians who say that education is not a primary need in India. As a society, we do not believe in education.

I think that these attitude-problems apply to the educated middle class, even in their role as parents. The character of our middle class is changing rapidly. With increased affluence has come a dedication to material goals, for which education is but one means. We do not question the quality of learning, as long as we are able to acquire the degrees.

So what should we expect from our schools? Let us go back to the Chinese and Japanese schools to see what happens there. The teaching profession is highly respected. Salaries are high enough to inspire bright young graduates to go into teaching. Even novices earn more than white-collar workers in business and industry with similar educational backgrounds. Teachers have a reasonable teaching load and frequent in-service education.

Compare this with our typical primary schools, where teachers are in classroom continuously for six to seven hours, apart from the school breaks. Even in relatively affluent private schools, teachers are ill-paid, overworked, and shown scant respect.

Japanese and Chinese teachers have enough time between classes to prepare lessons, consult other teachers about techniques, correct papers, and work with individual students who need help. Institutionally, there is an environment in which professional development is valued. Teaching is a co-operative activity. Experienced teachers help newer recruits and groups of teachers exchange notes on lesson planning and framing questions.

The actual techniques used by these teachers simply involve skilful application of well-known principles, for which they have the time and energy. Their task is also made easier by an interested and motivated group of students, who do not have to be constantly exhorted to keep quiet. These could be our children and our schools. Are we willing to take the lesson?

The author is with the Homi Bhabha Centre for Science Education, Bombay. This column appears once a month.

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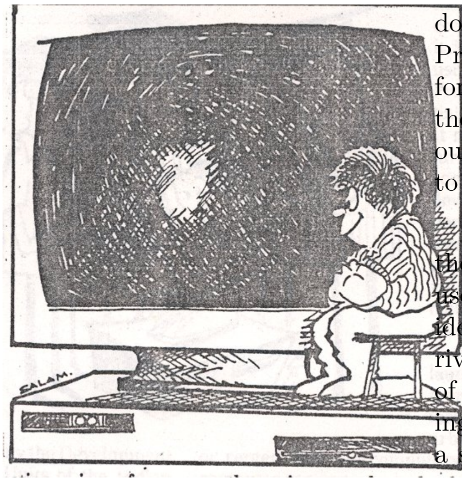
JAYASHREE RAMADAS

Learning byte by byte



In the recent budget, computer education in schools has received boost, with an allocation of Rs. 26 crore. This is possibly at the expense of the laboratory programs of secondary schools. Are we talking about the icing when we do not even have a cake?

Depending on one's vantage point, there are different approaches to the use of computers in schools. One would be to exploit the latest technology, without much worry about resources constraints, taking into account current educational thinking and research. Another is to select ideas which seem desirable and practical for the implementation in schools. A third one is shaped by ground realities in classrooms.

Today we will concern ourselves only with the potential of present-day computers, and what has been done with them, mostly in small 'Pilot Projects', in other countries. A plan for how best computers can be used in the Indian context has to emerge out of our unique conditions and experiences to which I will turn next month.

Computers came into education in the USA in the nineteen sixties. Their use was closely associated with the idea of "programmed learning" derived from the behaviorist psychology of the period. This involved presenting the content of given subject in a step-by-step manner on a computer screen, asking the student some critical questions, and providing corrective feedback. These Computer Aided Instruction (CAI) programmes were available on mainframe computers and were used in undergraduate education in combination with automatic testing and record-keeping systems.

Computers become accessible to schools when microcomputers came on the market. The idea behind introducing computers was mainly to teach about computers, but there was also a strong movement towards developing educational software, generally known as Computers Assisted Learning (CAL).

In the last 10 years the rationale for using computers in schools has undergone a rapid shift in the West. What started out as a need for computers awareness , for becoming familiar with computers because they were pervading society, soon merged with an emphasis on computers literacy, or learning to use computer for vocational competence. The use of computers to support and supplement teaching also become widespread. Related hardware and software evolved greatly. Simultaneously, research has produced new insights into learning processes. Many people have looked to computers to implement the desire structural changes in classroom learning. The keyword now is ILE (interactive Learning Environments).

One of the pioneers of the current movement was Seymour Papert of the MIT, who developed the Logo computer language in the 1970's. Logo is now widely used in American schools, from KG to high school levels. The MIT group has undertaken a series of research projects to explore the educational possibilities of computers and Logo. In inner-city Boston I have watched children from poor families working with total absorption on tasks that called for understanding of more maths, science and technology than would be expected from most students of their age.

This idea is that children learn through designing and creating their own "artifacts" or "objects to think with". The computer is powerful and versatile tool that lets them do this. In particular Papert claims that programming helps children to improve their problem solving skills. The artefacts may be programs that drawn geometrical figures and diagrams in biology, or a piece of creative writing with graphics on the Logo word processor, or a toy car that is controlled by computers. School children create their own educational software and video games. Environment in schools is such that it allow free access to computers at all times.

The MIT group, in collaboration with the Danish toy company, Interlego, has developed Lego-logo, a combination of Lego building block and Logo programs. The blocks come with motors, gear and transmission assemblies, and touch and optical sensors. Using these children build their own machines, then write Logo programs which control them via an interface.

A descendant of Logo is "Boxer", developed by Andrea DiSessa and colleagues at the University of California, Berkeley. This system allows students to write programs with complex subprocedures. They can use these, for example to make explicit their ideas about a topic in science, and then work towards an acceptable representation of their knowledge. Boxer has been used successfully to create "computational microworlds", like a world of objects that obey Newton's laws. Experiments in these simulated environments enable a feel for how abstract laws work.

The coming of interactive videodisk players has led to development of multimedia software, which allows teachers and student to create document consisting of text, videos and graphics. This high technology is useful only it is used in educationally meaningful ways to encourage good design, clear concepts, critical analysis, and social skills.

Another technology that is being exploited for educational use is computer-based telecommunication networks. There are scores of international networks of school student communicating on topics ranging from metereology to the meaning of life. In one such project, ten thousand students around the U.S. are doing research on acid rain. They collect samples of water, analyse them, and communicate their findings to other student around the world.

This may all seem like a lot of glitz, and one might wonder, can meaningful learning not happen with a much lower level of technological inputs? Well, certainly it can. The question is, as Humpty Dumpty said, "Which is to be master?" In all the projects above the efforts is to actively direct the way in which technology impacts education. Within the resources available to us, that should be our concern now.

The author is with the Homi Bhabha Centre for Science Education, Bombay. This column appears once a month.

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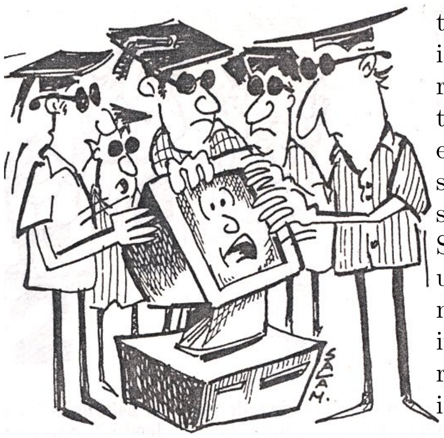
JAYASHREE RAMADAS

The ware is soft on education



Computers were formally introduced in Indian schools in 1984, with the "Computer Literacy and Studies in Schools (CLASS)" project initiated by the Department of Electronics (DoE). The question of priorities, uppermost in discussions at that time, is still relevant. Do we really need computers to the schools when even basic needs are not met? Is the euphoria about computers simply to divert attention from the real problems?

Despite these objections, the DoE expressed a firm committed to forged ahead with the project. The argument was (and still is) that education must be consistent with the national policy of computerisation. With computers envisaged as entering public services and private enterprises on a vast scale, computer training of the young must keep pace.

Of course, that argument has flaws: a scientific or technological advance, through revolutionary and far-reaching in its impact on society, is not sufficient reason to override educational priorities. Vocational training in computers can well be taken up at the post school stage. Unfortunately, the pressure to introduce computers in Indian Schools has less to do with their educational value than with social and market forces. But given this reality, it is still possible for educators to direct the way in which the technology impact school learning.

When the CLASS project was introduced in 1984, a fair amount of planning went into the preparation of objectives for the programme, designing a curriculum, working out the logistics of distribution and maintenance of the BBC microcomputers (in 250 schools to start with, now a few thousand schools), or teacher training and software development.

An early evaluation of the project, carried out in 1985-86 by the Development and Educational Communication Unit of the Indian Space Research Organization (ISRO), Ahmedabad, showed that the project was markedly more successful in the better-off schools. A major problem that come to light was the plethora of agencies involved in implementation. Lack of co-ordination and communication between the agencies led to a number of glitches in the implementation.

At the level of teachers, there were problems of adequate training, lack of motivation, and sometimes sheer disinterest. The project was expected to be carried out by teachers in addition to their existing work-load, without any monetary compensation. Especially in urban areas with their lucrative possibilities of private tuitions, the CLASS bait was simply not taken up by many teachers.

The ISRO study found that student were uniformly enthusiastic about working with computers, but in most case due to other limiting factors they did not get sufficient exposure to the machines. In exceptional cases when they did, the impact of the project was mostly positive.

It is an inescapable fact about computers that young people take to them more readily than to adults. Thus, a strategy that takes teachers' expertise as a pre-requisite to getting anything through to the students, is bound to run into a serious bottleneck. There may be a few highly qualified teachers who, especially if given a reasonable workload, are able to carry out a successful programe in their schools. But the majority of teachers need to completely reorient themselves and get used to being learners alongside the students.

Given the daunting task of large-scale teacher training, the CLASS project has had to keep to the modest objectives of "demystifying computers", which has consisted, for the students, of identifying parts of the computer, being proficient with the keyboard, and working through ready-made educational software. Sometimes when students get bored of the software, teachers encourage them to write programs, but they do not consider that to be a part of the "CLASS project", and are even afraid that they may be overstepping the limits of their duties.

This is a curious state of affairs, for the strongest educational justification for a computer in the classroom is the sense of empowerment that it can give to students. This empowerment comes from using the computer as a tool, making it do what you want it to do, using it to solve problems. Programming is an essential step towards this goal. It may even be possible to turn to advantage our low computer availability, by developing "computer support for collaborative learning", a sound pedagogical principle that involves groups of students collaborating on problem solving tasks.

A few years after the launching of CLASS, a more spontaneous movement come about it many urban schools, who bought or rented their own computers, supported by private computer companies who now design the courses and even the teaching. While this approach does away with the need for teacher training, it also often leaves educational objectives by the wayside. Students are made to learn word-processing, spreadsheet and database "applications" in a fairly routine manner, while the rest of the time they play computer games of a mindless variety. Of course, this system too has its survivors: there are some good trainers, as some students who do learn to use computers.

But it is time for the cart to stop blocking the horses in our schools and education considerations too get rightful priority. We should realize that computers by themselves cannot work wonders: they need to be part of a package that consists of good book books, laboratories and teachers. Also, since quality software is hard to come by and expensive to produce, such a package should not depend critically on the availability of software. Instead, introducing student to programming, preferably in a collaborative mode, can set them on the way to a satisfying learning experience.

The author is with the Homi Bhabha Centre for Science Education, Bombay. This column appears once a month.

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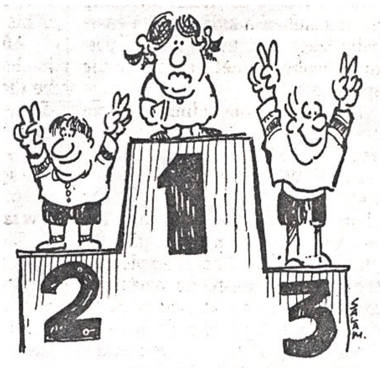
JAYASHREE RAMADAS

Imagined stereotypes



Since the time when girls first entered school in large numbers, their performance vis-a-vis boys has been the subject of conscious or unconscious evaluation. Although today most liberal-minded persons would deny that there are differences in intelligence between girls and boys, some stereotypes do persist. A popular idea is that if girls do well in exams, it is due to their hard work and 'cramming' which is, supposedly, a natural result of their docile and conformist nature. If boys do well, their success is more likely to be attributed to natural intelligence.

Is there any validity to such stereotypes? The evidence for sex differences in cognition, and their origin, is a controversial issue, to which I will turn next month. But there are more urgent practical considerations, to do with the school environment, which indicate that girls and boys may be actually learning differently in our schools.

Research on school performance in Western countries shows that girls as a group are ahead of boys in the early years, but then gradually fall behind. In India too, one is struck by the intellectual precocity of girls in nursery and kindergarten classes who, some years later, are turned into giggly, diffident adolescents. Though little comparable research has been done in India, there is some evidence that the male superiority in academic performance seen in Western countries may not be present here (although girls do suffer disadvantage when it comes to subject and career selection).

At the school level, our major problem is that of girls dropping out in large numbers. The 1981-82 figures of the Ministry of Education showed that 83.6 % of 6-14 year old boys were enrolled in schools, while only 53.6 % of girls were. Societal factors are blamed for this major debacle, and rightly so. But it is not often realized how much of the remedy of might lie within the school system.

A classic study, carried out by Rosenthal and Jacobson in the United States and published in 1968 under the title, 'Pygmalion in the classroom', showed that teachers' expectations can be subtly shape and alter the performance of students. A group of student were selected at random, but their teachers were told that these students had been identified as 'intellectual bloomers'. Eight months later these randomly chosen students showed significant gains in IQ scores.

Teacher expectations, reinforced by

societal stereotypes, could well affect, for example, the performance and self-concept of socio-economically deprived students, and likewise, the performance of girls. Studies of classroom interaction show that, in general, teachers in co-educational classrooms interact more with boys than they do with the girls. The boys in fact demand and grab the teacher's attention. In the bargain they get more praise as well as more disapproval, while the girls are simply passed and over and ignored. In India this phenomenon is striking in rural classrooms, where sometimes girls seems to be accepted more by sufferance than by choice.

The passive role of girls is actually reinforced by teachers when, for example, they intervene and complete a task for a girl who needs help, but a boy in a similar situation gets extended instructions on how to do the thing for himself. When a boy calls out an answer in class, the teacher often accepts and responds, while if a girl does the same, she is likely to be reprimanded and asked to raise her hand. The result is that girls become more helpless and dependent, while losing out on the teacher's time and quality of attention.

TEXTBOOKS are another part of the unwitting scheme which relegates girls to the background. Although there is a sea change from the time when we used to have science books addressed explicitly to 'boys', today's books continue to display a clear bias against girls. Studies done in Western countries as well as in India show that male-centered stories and illustrations dominate in textbooks. While boys are depicted as brave and ingenious, girls are often shown as powerless victims.

Science textbooks are particularly guilty in perpetuating the image of the active, experimenting boy accompanied by an occasional passively observing girl. Many schools institutionalise such stereotypes by offering subjects like computers and electrical maintenance exclusively to boys, while the girls do sewing and cookery.

Today, major publishers in the West have guidelines for non-sexist writing, which include instructions for providing roles models for both sexes, acknowledging the contributions of women, and avoiding sexist language. But the implementation of these guidelines has been slow.

The status of women in the curriculam received attention at the NCERT in 1975, when the report of the committee on the status of women in India was released. The NCERT followed up by a series of regional and national seminars on how values of equality of women could be incorporated in the curriculum, and in 1982-84 produced three teacher's handbooks on the 'Status of women through curriculum', with useful suggestions for highlighting the rights of women and emphasising competence in both girls and boys. But their suggestions for science teaching did not go much beyond including examples of household science.

The NCERT textbooks published recently, however, do show some attempt at a avoiding sex-based stereotypes and male-centered language in textbooks. To a lesser extent, this attitude is percolating into state government textbooks too, but there is a long way to go. A popular series of science textbooks used in private Bombay schools still shows a casual indifference to the presence of girl students.

Today, many of the more fortunately placed girls are overcoming such hurdles and confidently entering male-dominated fields. Still, the majority continue to suffer discrimination.

The author is with the Homi Bhabha Centre for Science Education, Bombay. This column appears once a month.

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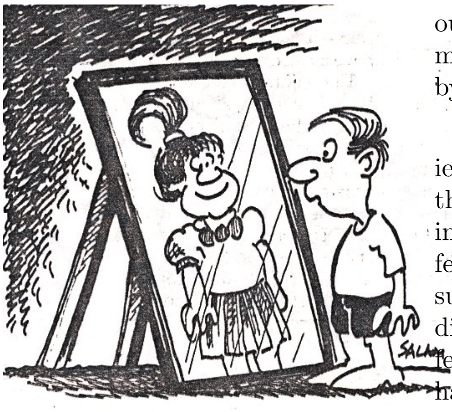
FIRST PRINCIPLES

JAYASHREE RAMADAS

Tapping womenpower



Is it true that men are rational and scientific while women are emotional? Do girls and boys differ in their thinking? These are among the most difficult question for psychology, for stereotypes play a major role in shaping our behaviour as well as our perception. Although much research has been done in this area in the West, analysing its results is a daunting task, since no researcher or editor of a scholarly journal can claim to be free of bias.

The responsibility was undertaken by two psychologists, Maccoby and Jacklin, who published in 1974 a book called "The Psychology of Sex Differences". The late 1960's had been the era of large scale biologically oriented theories of human behaviour. Biological determinists sought to show that much of human behaviour, including the so-called sex differences, were genetically determined and selected by evolution. But Maccoby and Jacklin's survey of research took the thrust out of such arguments by showing that many of the sex differences "explained" by biologists actually did not exist.

This in spite of the fact that studies which found no difference between the sexes had a hard time getting into print, as research journals preferred demonstrations of positive results. The vast unruly mass of data did yield a few small yet consistent differences between girls and boys. Girls had slightly higher scores on "verbal abilities" and boys on "visuo-spatial abilities". These differences held on the average: they were not large to predict differences between individual girls and boys.

Little girls often learn to talk before boys do. Their speech also becomes complex earlier, which might give them an advantage over boys in the early years of school. This early verbal precocity is reinforced by sex-role stereotypes so that as they grow up, girls tend to prefer reading, writing and verbal modes of thinking.

But even this apparently "innate" difference between girls and boys is highly susceptible to influence of stereotypes. Research shows that students do well on reading if they perceive task to be sex-appropriate. If boys see reading as an acceptable masculine activity, they perform as well as girls do. It interesting that over the last 30 years, sex-differences in verbal abilities have been apparently decreasing.

Visuo-spatial abilities include findings one's way around a town or building, reading maps, mentally rotating two and three-dimensional objects, playing chess, solving mazes and doing jigsaw puzzles. These abilities are also called on in learning mathematics, physic and chemistry. Typically, differences in visuo-spatial abilities between girls and boys appear around adolescence, although some studies find differences even earlier. Adolescence being the time of intense hormonal changes and also the time at which the sex-roles become strongly differentiated, both biological and environmental determinists have claimed the spatital ability results to support their own viewpoint.

The effects of environment, however, are easier to see. Sex differences in science and mathematics achievement, and in visuo-spatial ability, vary considerably from country to country. Differences are particularly marked in countries were where women play a submissive role and are confined to the house, while they are non-existent in other parts of the world, for example, among the Eskimos, where women enjoy equal status and freedom to exercise all their faculties.

Visuo-spatial abilities can be easily taught. The more the number of mathematics courses taken by a student, the better are his or her scores. As more and more girls have started to take higher mathematics courses, the sex difference in visuo-spatial abilities has decreased.

Sex-role stereotyping in schools is strong. Girls in single-sex schools do better at maths and science than girl in co-ed schools, while for boys the opposite is true. A likely explanation is that when girls and boys come together to learn, it is the boys whose seize the advantage, while girls perhaps try to play down their own abilities in order to conform to their "feminine" roles.

Early research on sex differences had often assumed that the school provided identical experiences to girls and boys, so any differences in performance must be due to innate factors, or perhaps socialisation outside the classroom. But when strong stereotyping in schools became obvious, the focus changed to what could be done via education. Even if some innate differences exist, the evidence suggests that these can be overcome largely by the schools.

The largest differences in girls and boys actually seems to lie in factors like values, attitudes, motivation, self-confidence, and career orientation. Girls seem to driven to a kind of learned helplessness and a fear of failure, reinforced by society, by educational practices, and by sexist messages in the media and the textbooks.

One such factor serving to alienate girls is the masculine image of maths and science. A recent issue of the journal *Science* has a special section on "Gender and the Culture of Science". In it several scientists explore the idea that there may be a special "female style" of doing science which differs from the dominant style featuring "Man as a conqueror of nature".

Several recent science and maths curricula being developed in the West emphasise the need for "girl friendly" teaching materials. One of the things they are trying to do is to reduce the masculine images like guns, cannons and footballs in subjects like physics.

Research also shows that the detached, overly rational image of science, unrelated to personal and social concerns, is harder to accept for girls than it is for boys. Many programmes find that when the real world relevance of science is bought out, girls are motivated to learn. And they will need to be, as a society grappling with awesome global problems cannot afford to lose out on the brain power of women.

The author is with the Homi Bhabha Centre for Science Education, Bombay. This column appears once a month.

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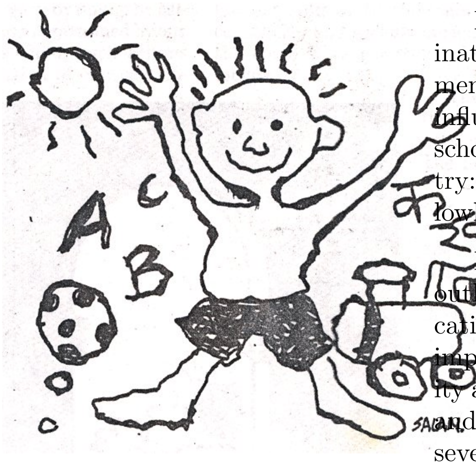
JAYASHREE RAMADAS

Spirit of the child



August 31 is the 123rd birth anniversary of Maria Montessori, whose creative genius has deeply influenced educational thinking worldwide. It is also exactly 20 years from the death of Tarabai Modak, whose centenary was celebrated last year. In her 50 years of active work, Tarabai ably adapted Montessori's ideas to bring about a minor revolution in popular notions on child development, child rearing and education.

Montessori stimulated a considerable amount of original work in India on early childhood education. Yet in the competitive tussles of today's academic world, our pre-primary schools have degenerated to training children to read, write and memorise in what is hoped is the quickest possible way, so that the primary schools might get on with their job of imparting information.

But the power of ideas which originated 150 years ago and the commitment of those who came under their influence have kept the lamp alight in schools scattered throughout the country: from posh Bombay suburbs to lowly tribal Balwadis.

Friedrich Froebel was the first to outline a systematic method of educating young children. He showed the importance of learning through activity and exploration of the environment, and he started, in 1837, the first of several kindergarten schools in Germany. Froebel's kindergartens were viewed by the Prussian government as being too revolutionary, and were eventually closed down. But his ideas had taken hold, and moved out into Europe and the United states, were Christians churches incorporated them in their parish work. It was European missionaries who, towards the end of the nineteenth centaury, introduced kindergarten education into India.

Next came Maria Montessori, the Italian medical doctor who started her educational work with children classified as mentally deficient. People were amazed when these children were able to pass the state reading and writing exams for normal children. But Montessori saw her result differently. She thought, if her "retarded" pupils could compete with normal children simply after better teaching then the latter must have, in effect, been hampered, "suffocated", in their regular schools. If her educational methods could be applied to normal children, the results would be even more startling.

The central idea in Montessori's philosophy is that children take a natural pleasure in learning to master their environment, a process which starts with their manipulation of objects. With this in mind, Montessori designed a series of educational toys that would systematically develop the child's sense perceptions.

Montessori started, in 1907, a series of schools for slum children in Rome. Within a few years, the spectacular success of these schools was known all over the world. During the Second World War, Montessori came in India, where between 1939 and 1949 she spent more than eight years.

Shri Girijashankar "Gijubhai" Badheka, the most devoted India crusader for Montessori, popularised her methods throughout Gujarat and Maharashtra. But by his creative thinking and commitment to adapting this system to the Indian culture, he also brought into focus the rather rigid and uncompromising attitude of Montessori herself, who objected to his use of her name. Eventually, the Indian Montessori Society established by Gijubhai was re-named "Nutan Bal-Shikshan Sangh". Under the leadership of Smt. Tarabai Modak, it kept alive the Montessorian spirit while continuing to do original work in the Indian milieu.

The same dogmatic attitude taken by Montessori towards her followers in USA led to the almost total extinction of her methods in that country. Where her ideas did survive, they were enshrined in the form of a closed cult rather than becoming part of the educational mainstream. The kind of enthusiastic reception that Montessori received in India was unmatched anywhere else in the world.

It was perhaps the mystical nature of Montessori's belief, her view of education as a process of liberating the spirit of the child, that found resonance in the Indian psyche. At the same time, her very practical classroom methods, her stress on working with the hands, fitted in with Gandhian ideals. Recently, the discovery by cognitive psychologists of the close relation between sense perception and cognition, and research on the crucial importance of early experience for late development, has vindicated many of Montessori's ideas. In recent years Montessori has been rediscovered in America.

Tarabai Modak's experiments with Montessori led to the adaptation of these originally rather costly methods to rural and tribal education. Today, local materials like clay, wood, seeds, shells and dyes, and the creations of village artisans, used in innovative ways in *Balwadis* and *Anganwadis* in Maharashtra.

Tatrabai's most prominent contribution is perhaps her writings for children and adults. She translated difficult concepts of child psychology into stories and anecdotes that seem as revelent today as they must have been half a century ago. When Tatrabai started writing for children, the only literature available in Marathi was for children above eight years. Also, the trend was to be either self-consciously moralistic or excessively informative. Tarabai's stories and poems, written in spirited Marathi with a sense of rhythm and drama, have provided a model for later writers.

Today, if we are move willing to accept children as competent human beings able to take on new challenges, and if we are more sensitive to their early educational needs, it is entirely due to the efforts of these pioneers of early learning.

The author is with the Homi Bhabha Centre for Science Education, Bombay. This column appears once a month.

THE ECONOMIC TIMES

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FIRST PRINCIPLES

JAYASHREE RAMADAS

Early, but correctly

Why send a three year-old child to school? Educated parents are in no doubt about the answer: their child must have a early start. Primary schools are clear too: their job is easier if the child at entry is already proficient in the basic skills. The "kindergartens" do their best to meet these expectations, while trying to implement some version of their "principles of early childhood education".

But parents who are handed a stiff progress-card and a sheet of paper outlining next term's syllabus for the Junior KG, are sometimes left wondering: is all this adding up, or are we just caught up by some fad?

Experts say that two-thirds of our ultimate cognitive ability is formed by the time we are six years old. This rapid intellectual development does not simply happen by a natural unfolding of innate potential. It is critically shaped by experiences in the early childhood years: years which are also crucial for the social and emotional development of the child. It is in these years that environmental factors exert the strongest influence on a child's development.

This is not to imply that external factors impact on a passively absorbing learner. We learn by doing: by acting on the environment in a manner determined by our innate potential. For the young child, such actions most often involve the manipulation of concrete objects. Pre-school education is concerned with the kind of learning and development that occur in early childhood, and the appropriate experience which can help it along.

The most visible change in the early years is physical growth, including an increasing control over one's body. The clumsy toddler who is constantly tripping, falling, and dropping things, has to be transformed into a competent, well coordinated five year-old.

On the island of Manus, Anthropologist Margaret Mead observed children who had to daily negotiate the dangerous waters of their lagoon homes. Seeing their physical agility and finely tuned sense-perceptions, Mead wondered about the effects of experiences on sensory-motor development. Neither high-rise flats nor city slums afford the kind of environment necessary for good physical development. A kindergarten with well-designed outdoor equipment can try to make up for this loss.

Along with the development of large motor abilities, comes control over one's finer actions. Even the task of holding a pencil and moving it in a controlled fashion, needs precise control over the hand muscles, and a co-ordination between eye and hand. The nursery school activities of putting pegs in a pegboard, threading beads, molding clay, and fitting pieces of a jigsaw, are all useful for this.

Intelligence is described as an ability to successfully adapt our actions to the environment. There are many facets to this ability. Pre-school is the time when children learn the concept of number, logical relationships like class-inclusion, geometrical ideas about shapes, cause-effect relationships; they learn about living things around them, about properties of materials, the list could go on. This is the time when children acquire the building blocks of cognition, which they will, in later life, organize into more or less elaborate structures.

This is also the time when they learn whether creative thinking is acceptable to the society around them, or whether their jobs is to absorb and exactly reproduce what they are told. They learn to appreciate and to express themselves through language, art and music.

A major aspect of cognitive development during infancy is the acquisition of language. The role of the pre-school teacher is to help children enrich their language, to enable them to express complex and abstract ideas. There is vast difference between an oral and a literate mode of language use. Through the medium of stories and rhymes, children learn about different ways of using language, they learn to derive pleasure from words.

The best medium for all this is the child's mother tongue, or a second language in which the child is at ease from an early age. The rush for English medium pre-schools, without a strong background of English at home, results in the child missing out on many of the cognitively and socially enriching experiences which she could have got from education in the mother tongue.

There are many others things that can and should happen in a good pre-school. The development of personality characteristics like initiative and self-confidence, social skills like sharing and cooperation, moral other standards for dealing with people around, are all part of the task for the pre-school.

These are all quite realistic ideas which have been implemented in different forms. On a large scale, pre-school education was tried in the USA in the sixties and seventies, with the ambitious aim of decreasing the social gap in education opportunities. Titled "Project Head Start", it was aimed at children from poor Black families. Early evaluations of the programme were disappointing, but longer-term studies showed that children involved in the project had a higher rate of school completion, and better employment prospects, than did a control group of children.

India too has had a number of pioneering experiments in early childhood education. Yet, today, there are very few pre-schools which approach the ideal. In big cities, nurseries are run in cramped rooms with little equipment and no realisation that professional training is needed for pre-school teaching. Educational equipment remains shoddily produced and not easily available.

We are seeing a disintegration of the traditional apparatus of early education – the joint family and the village community – but as yet we have evolved no substitute for it in the modern society.

The author is with the Homi Bhabha Centre for Science Education, Bombay. This column appears once a month.

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FIRST PRINCIPLES

JAYASHREE RAMADAS

Seat-of-the-pants physics

If you are reading these words, there is a good chance that you are graduate, and a fair one that some time in your school or college career, you have learnt about motion and Newton's laws of motion. The context is familiar enough; objects being pulled, pushed, thrown or left alone. Let us consider some questions about throwing.

- You throw a ball straight up and catch it as it comes down. What is the acceleration of the ball at its highest point?
- Is there a force on the ball, and in which direction, as it goes up, at the highest point, and as it comes down?
- You throw the ball straight up, but now facing forward in a closed compartment of a uniformly fast-moving train. Will the ball fall back in your hands, or will it fall behind you or in front of you?

Whether or not you remember any physics right now, take a minute's pause to see what your intuition says about these questions. You will not be alone, for all over the world teachers and researchers are asking such questions to school and college students, to physics graduates and post-graduates and to ordinary persons-on-the street.

The results are remarkable uniform. Irrespective of their physics education most people think that the ball's accelerations is zero at the top of its trajectory, that the force acts in the direction of the ball's motion (in the upward direction when moving up, zero at the top, and in the downward direction as the ball comes down), and that the ball thrown straight up inside a uniformly moving train will land behind the thrower, as the train has moved forward since the time it was thrown.

Such ideas are close to those held by philosophers three hundred years before Newton. Even today, students have similar intuitive theories about motion which are contradicted, but not fundamentally challenged, by school learning.

In fact, the acceleration of a ball thrown upwards is constant throughout its flight. Once the ball leaves your hand, the only force acting on it is gravity, which always acts straight down, whether the ball at that moment happens to be going up, down, or sideways. Another minor force is air resistance which – for a ball that is not spinning – acts in the direction opposite to its current direction of motion.

Why then do people consistently imagine that the force is in the direction of the motion? Part of the answer might lie in the fact that the simplest (school) examples of Newton's laws occur in an idealised frictionless world, where moving objects with no force acting on them keep on moving in straight lines. In the real world, which is full of friction, an object with no force acting on it apparently comes to rest. It is natural to infer from this experience that anything which is moving must have a force acting on it in the direction of its motion: like the whimsical spaceship in a science-fiction film which coasts at constant velocity with its rockets firing continuously.

But, imperfections of the real world apart, sometimes our mind seems to reject even what the eye can see clearly.

The correct answer for the ball thrown up in a moving train is that, even after it has left your hand, the ball continues to move forward with the same velocity as that of you and the train; so it falls right back in your hand, and not behind you, as most people imagine. This counter-intuitive behaviour has foxed many a novice football player who misjudges the direction of a pass.

One interpretation is that such a mistake results from visual illusion. Studies in the perception of motion show that when an object is viewed against a moving frame of reference, its trajectory with respect to that frame is mis-perceived as being one relative to a stationary frame of reference. Even when we ourselves are in a moving frame (that is, running, or inside a train, we remain mentally bound to the ground).

Naïve theories, as I wrote in this column in January, must occur not only in physics, but in all areas, since our everyday experience with the world is being constantly interpreted by an invisible, active mind. Clearly teaching must in the some way take account of intuitive ways of thinking. A teacher who knows of the lurking preconceptions of students can start by helping them get their ideas out in the open. What is needed is a restructuring of the students' existing knowledge, rather than simply imparting new information. Thus the traditional linear presentation of the subject matter must be replaced by one structured to maximize linkages, between related concepts, between chapters of the same book, between what has been learnt this year and the previous years, between different subject areas, and between the text book and life experience.

Another successful instructional strategy, deriving from computers, is to present knowledge not in a "declarative" but in a "procedural" form. Most present teaching is declarative, that is, we give descriptive definitions which we ask students to remember. A procedural definition, in contrast, would specify the steps to follow in order to construction an instance of the concept.

To teach about "force", one would try to come up with instructions in various contexts: how would you tell whether there is a force acting on a given object? How can you feel, or apply force physically? How would you measure a force? How would you show it in a "vector diagram?" How would you write an equation for it, and so on. Briefly, one tries to go from "knowing that", to "knowing how". In doing so, one ensures that hands-on experience takes precedence over rote learning.

The author is with the Homi Bhabha Centre for Science Education, Bombay. This column appears once a month.

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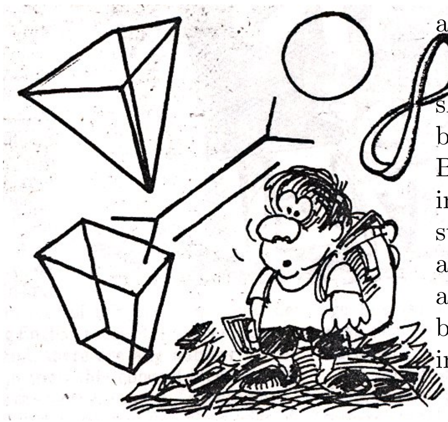
FIRST PRINCIPLES

JAYASHREE RAMADAS

Foundation in concrete



Abstractions are the stuff of science. In everyday life we might experience things as hot and cold, but the "heat" in physics cannot be felt. It is an intangible entity that flows, but lacks the familiar properties of matter, is not sensed by a thermometer and is only written in mysterious equations.

Innumerable such abstract ideas like work, gravity, valency, ecosystem, evolution, occur in school science. Mathematics of course has a rich repertoire. Ideas like operations, functions and solution sets are highly abstract, say teachers, and most students are simply unable to grasp such abstract concepts.

This view is confirmed by experience. Teachers' repeated explanations of these difficult concepts do not help. At most, students are able to remember definitions and rules and those too, just long enough to pass examinations. Ask them about it a few months later, and you are met with blank stares.

Research into students' learning shows that indeed students have trouble with abstract concepts in science. But they also have a strategy for dealing with them. What they do is to substitute the original abstract idea with a plausible concrete model. For example, students spontaneously think of both electric current and heat as flowing fluids.

However, this kind of substitution leads to misunderstandings. If current is a fluid, how can it be both conserved as it circulates, and yet wear out in the battery? Research done at the Homi Bhabha Centre for Science Education has shown up a number of such misconceptions with students in Bombay schools.

When the textbook says that the earth acts like a magnet, students conclude that there is a large magnet buried inside the earth. They think of light rays bumping against each other. Even college students, in trying to understand the abstract notion of "frame of reference", imagine it to be a physical space, defined by the extension of particular objects. As a result, they come to absurd conclusions in which frames of reference collide, fragment and merge.

In biology, this research finds students replacing the abstract idea of Darwinian evolution by a concrete Lamarckian notion, in which the environment directly affects physiological characteristics. It is easier to imagine the giraffe getting a long neck by having to stretch himself towards high branches than to think of ideas like variation and natural selection.

Does all this mean that most students are incapable of learning abstract concepts?

Such a conclusion is perhaps too hasty. For over a hundred years now, anthropologists and psychologists have tried to demonstrate that primitive, pre-industrial societies lack the capacity for abstract thought. But they have repeatedly found that although "primitive" people might fail on formal tests, they show very subtle reasoning in areas of their own experience.

Consider some abstractions which we make in our daily lives. We talk about systems like the political system, the bureaucracy, the transport system. Uneducated farmers are able to make cost-benefit analyses; stock market investors habitually use complex ideas like price/earnings ratio and net asset value. Any one of these abstract concepts is understood and developed into its nature from over a period of months or years.

For example, around the age of seven to eight years, there is a major shift in the ways in which children describe other people. While earlier they used highly concrete categories like age, sex, physical appearance and routine habits, they now start to use more abstract and inferential categories like personality traits, motives and attitudes. As they grow older, these notions become even more sophisticated, to include explanations of behaviour and situational variables.

Why is it that the sophistication seen in, say, an understanding of human personality, is not seen in understanding of science?

The answer lies in experience. From childhood, we have had extensive experiences of dealing with different kinds of human personalities. We make a large number of observations, develop our own theories of behaviour, experimentally test out these theories and continually modify them.

In contrast, theories and abstractions of science and mathematics are doled out to us ready-made. We do not have a chance to see them in action, to question them, to test them, and to form our own judgements. If this process were to start early enough in primary school, the density of concepts experienced in the later classes would not seem so overwhelming. This calls not only for better curriculum planning, but a higher quality of training and resources for teachers.

When students invent their own concrete models, they are making the best of the given situation. In fact, they are doing what most scientists do when they develop new constructs or try to understand old ones. When Michael Faraday introduced "lines of force" to express the arrangement of magnetic forces, he did not confine himself to abstractions. He actually thought of the lines as stretched strings which could vibrate, expand and contract; and this idea helped him to conceptualise electromagnetic induction.

If the students' models are inadequate compared to those of scientists, it is simply because they are based on insufficient knowledge. They do not include the essential elements of the physical reality which they aim to describe. It needs a great deal of ingenuity to invent models which are close to reality, which are not so abstract as to incomprehensible nor so simplified as to be meaningless. Again, students need to discuss to what extent any model deals with a given problem, and what its limitations are. Fortunately, with the beginnings of popular science writing in India, a few authors have started to tackle this problem.

The author is with the Homi Bhabha Centre for Science Education, Bombay. This column appears once a month.

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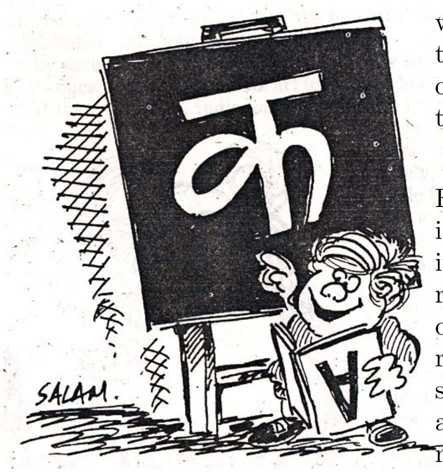
FIRST PRINCIPLES

JAYASHREE RAMADAS

Mother of all tongues



Should technical subjects be taught in the mother-tongue? This is highly emotive, sometimes explosive issue. It has been discussed, debated, ignored and exploited for many years now. Recently, during the annual 'Founder's Day' celebrations at the Tata Institute of Fundamental Research (marking Dr. Homi Bhabha's birth anniversary), this topic was selected for a popular debate. As expected, emotions ran high, sometimes eclipsing the real educational issues.

The problem is a complex one, especially in the context of a plural, multi-lingual society like ours. At the popular level, it is often seen as a conflict between emotional and pragmatic thinking. The arguments in favour of the mother-tongue see language as a tool for oppression, and stress the need for preserving one's cultural heritage. The counter-arguments are concerned with practical difficulties of implementation and of translating the already overflowing technical literature into all the regional languages of India.

Both sides, unfortunately, perceive English medium education to be an intrinsically superior alternative, since it appears to open up an attractive range of career opportunities. Students from vernacular medium schools rightly complain that when technical subjects are taught in English, they are at a disadvantage *vis-a-vis* English-medium students. It is the latter who get the coveted seats, who corner jobs, and generally get ahead. But no one could seriously believe that the social inequities which lie at the root of this problem, could be wiped out by making English accessible to everyone.

On the other hand, there are any number of research studies which show that concept formation is most sound thought the mother-tongue. Learning happens best when it builds on natural thought modes of the child. Children who are forced to learn in an unfamiliar language, not only develop negative attitudes towards school, but also lag behind in their understanding. Lack of language fluency results in a tendency towards rote learning. In exams, these students look for key-words and recall answers from memory, rather than trying to analyse the questions put to them.

The interaction in the classroom also suffers, as teachers generally lack the skill to conduct meaningful discussions in their second language, while students are unable to express their own ideas clearly. In a linguistically mixed classroom, teachers (inadvertently) pay less attention to students who lack language proficiency. When they do interact, the studies show, it is in a managerial rather than an instructional mode.

Children become fluent in two languages if exposed to both of them systematically from birth. In fact, such children enjoy far-reaching cognitive advantages in later life. But if the second language is introduced at the age of 7-8 years, before the first language is learnt perfectly, then both languages suffer. A better strategy is to start the second language at about 10 years of age, after the first language is well developed.

Language ability is crucial to learning maths and science. Many recent school programs have found that when the teaching of language is linked to symbolic skills, students become better at mathematics. The traditional notion that 'arts' subjects require language proficiency, while 'science' subjects do not, has been discredited by research.

Educationists have long realised the importance of learning through the mother-tongues. But the Indian system of education, due to its ambivalence of purpose, has ignored this sound principle. Almost 160 years ago, Lord Macaulay laid out for us the policy of imparting western knowledge through English for the elite minority. Since then, starting from the Hunter Commission of 1882, various committees and commissions on education have recommended giving priority to school education in the regional languages. The All India Universities Conference in 1939 and the University Grant Commission in 1960 argued for education in the mother-tongue till the degree level. But the ghost of Macaulay continues to reign over us. Our policy makers, and worse still, the common people strongly believe in the basic inadequacy of Indian languages.

It is clear that at scientific research level, in commercial, financial, diplomatic and other spheres calling for national and international transactions, the use of regional languages would be impractical. English is essential as the link language, and it needs to be taught, in the right way and at the right age. But, as a second or third language, English will always remain an inadequate vehicle for meaningful learning.

The question is whether we can continue to give our children such highly adequate tools of learning. All research in this area shows that at least one well-developed language is essential for learning any subject. At present, most of our children, even those in elite English-medium schools, know how two or three languages, but none of them well enough to express themselves on any subject with clarity.

Our schools for mass education – the government-run schools – do offer education in regional languages. Degree-level education in regional languages is also available, particularly in non-metropolitan areas. But in any society, it is the elites who set norms and if they look on regional languages as a second rate option, then so do the masses. In striving to attain the ideal English education, they irreparably damage any spark of creativity in children. At the same time, the regional language schools suffer the effects of a self-fulfilling prophesy. They either remain inadequately equipped, or get taken over by narrow sectarian interests.

The vast change in public perception is needed if our educational system is to throw up a reasonable number of genuinely original and creative individuals, who can hold their own in a fast-changing world order.

The author is with the Homi Bhabha Centre for Science Education, Bombay. This column appears once a month.

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FIRST PRINCIPLES

JAYASHREE RAMADAS

Toying with bright ideas

It's Santa Claus time. Kids all over the world, in anticipation and excitement, are opening up assorted packages rustled up for their enjoyment or education. In India too, this is a busy period for the toy industry, which has seen more changes in the last two decades than at any time before.

At the heart of the change is the fact that urban parents have become more discriminating. Instead of casually buying a doll or a toy car as a present, they are looking for quality, for novelty, and above all, for that elusive 'educational value'. Toy manufacturers too are responding to the demand. Educational toys range from those designed to prepare children for the all important preschool interview to those aimed at young adolescent 'scientists and engineers'.

Educational toys and games generally conform to a certain kind of stereotype. The popular, but misguided, view is that they should teach important facts, and supplant academic disciplines with more palatable forms of learning. Few children are taken in by such window dressing, and after sizing up the new educational toy, they return to their Barbie Doll or GI Joe.

Today's well-to-do parents are spending more money then ever before on toys. But they often find that instead of playing with these expensive and sophisticated toys, children occupy themselves with odds and ends that would have otherwise been consigned to the garbage. This is not merely a perverse lack of appreciation of the good things that their parents have worked hard to get. Rather, children instinctively look for playthings that provide the maximum stimulation. Smooth edged plastic toys, or cuddly soft ones, simply do not provide the variety of sensations and experiences that sticks and seeds, or shells and feathers do. Pre-fabricated assembly kits do not allow much scope for a child's inventiveness. Whatever interesting toys there are available on the market, tend to be replicas of those found in the West, and often bad ones at that.

In recent years, some voluntary popular science initiatives in India, like the Kerala Shastra Sahitya Parishad and Eklavya in Madhya Pradesh, have tried to develop and propagate educational toys. Two of the most creative and prolific developers have been Arvind Gupta, a Delhi-based freelance educator, and Sudarshan Khanna of the National Institute of Design, Ahmedabad. While the former works on scientific toys, the latter is more concerned with conveying principles of design through toys. Both make use of ordinary materials like old newspapers, matchboxes, broomsticks and even discarded rubber chappals, to make ingenious gizmos. Khanna has built up a collection of traditional toys made by children from different parts of India. These designs use local materials and they have been passed down and perfected by generations of children. Usually ignored by parents, the toys have genuine educational significance. Spring loaded carts, whirligigs and whistles, can be used to illustrate scientific principles, and to understand properties of materials. Khanna points out that the process of planning and constructing a simple dynamic toy can develop a high level of skill in children.

This intuitive idea is supported by recent research in knowledge and cognition. Most people imagine that there is a clear distinction between theoretical thinking, characteristic of philosophers and scientists, and practical work of arisans. However, the way that different thought-modes develop, particularly in children, is actually through a variety of manual actions. In the act of constructing, children learn to think.

When the 17th century English philosopher, John Locke, propagated the powerful notion of "teaching through sport", he provided the rationale for the first toys manufactured specifically for children. However, toys as a folk art form have been around since antiquity. India has a tradition of these toys, which are sold at street corners and local 'melas'. Unfortunately, these toys are made from scrap materials, and often they are unsafe because of sharp edges, rusted metal, or toxic paints. But Khanna, who has catalogued toys and learnt from toymakers, finds that many innovative design ideas are employed here, some of which are dying out.

Often, traditional toy makers belong to the lower rungs of society and they carry out their jobs as a routine economic necessity. In the absence of any appreciation of their craft and incentive to develop new designs, they continue to use ideas evolved perhaps hundreds of years ago. But if provided with resources, they ought to be able to contribute to development of toys of educational value. This process has already happened in Europe and US, where inventive toys of local craftsmen were taken up in an organised way of crafts councils for mass manufacture by private entrepreneurs. In India, we have clever, but badly produced local toys gradually losing out to cheap plastic ones, while the upmarket fare displays a curious poverty of ideas.

Our vast numbers of schoolchildren could become willing participants in any enterprise to preserve and revitalise this important sector. A start could be made with the craft classes in schools by providing incentives for development of new designs. Both the toy industry and the educational establishment have a role to play here.

The author is with the Homi Bhabha Centre for Science Education, Bombay. This column appears once a month.

THE ECONOMIC TIMES

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FIRST PRINCIPLES

JAYASHREE RAMADAS

Knowing the world, naturally

The launch of the Sputnik in 1957 triggered off an intense questioning of educational standards in the USA, eventually leading to a worldwide movement for curriculum reform in school science. The movement was led by prominent scientists, who insisted that the manner in which school science and mathematics were taught was completely wrong. Traditional teaching methods encouraged rote memorisation of facts, whereas science is really a process of enquiry, a method of discovering the natural world. What could be a better ideal then, than teaching science through discovery?

The scenario of an ideal discovery-learning classroom is one where the teacher is no longer the sole arbiter of knowledge, but only a guide and helper. Teacher and students together raise questions, design and carry out investigations, discuss and analyse the results, and draw their own conclusions. The aim is not to learn facts, but to acquire the tools of learning.

These curriculum development efforts in different countries were directed and executed by some very prestigious scientists. The books which came out were of high quality and incorporated many innovative ideas in teaching. But when it came to the implementation of the ideal scenario in typical classrooms, several problems arose.

Perhaps it is difficult to encapsulate discovery experiences into simple curriculum packages. Only a small minority of students and teachers took to the new materials; the majority did not see the point of learning through discovery. The process of experimentation involves formulating hypotheses, seeing the relevance of different variables, knowing which of the several outcomes to observe, and finally, arguing about the interpretation of the findings. Even most teachers, despite training programmes, were ill-equipped to handle such complex situations.

The sad fact is, that there is no panacea to the problem of teaching. The discovery approach turned out to be highly dependent on the background and learning styles of individual students and teachers. Those teachers who were not at ease with the sudden freedom forced upon them, went back to teaching the new materials in their old ways, emphasising rote memorization of the results of "investigations". For the students too, it became the old game of guessing what "results" they were supposed to get, or what was the answer that the teacher wanted them to "find out". If the experiment did not work – that is if it gave unexpected results – teachers were forced to tell students the correct answer, thus furthering an authoritarian image of science, one that the new methods had been specifically designed to counter.

The emphasis on science as a process of enquiry was surely a healthy counter to the older fact-centred approach. But when done with the kind of apostolic fervour that it was, it swung the pendulum too far in the other direction. Students tended to become sceptical of anything that their teachers told them, and to disbelieve even generally accepted scientific facts. The insistence on teaching everything through inquiry sometimes made the curriculum too contrived.

The idea that one can find out everything for one's self, holds within it certain assumptions about knowledge, about science, and about learning. It assumes that knowledge is unproblematic, and can be obtained simply by unbiased observation and correct application of the scientific method. This view has long since been rejected by philosophers of science, who have pointed out that observations made by scientists are always influenced by their theoretical expectations. This is equally true of students, whose "observations" often only reinforce their prior misconceptions. The philosophy behind the inquiry approach (in its dogmatic form) is therefore, basically flawed.

Perhaps the most heavily criticized aspect of the new curricula was that the highly qualified scientists who developed them had little experience of school teaching. Although some amount of field testing of the materials was carried out, and teachers and administrators were supposed to provide feedback, these inputs did not sufficiently influence the content of the curricula.

The Indian experience, though similar in essence, has not been so well documented. In the early years after the founding of the National Council for Educational Research and Training (NCERT) in 1961, some of the American curricula were tried out with Indian students, with little success. Their drawback was a heavy overloading of content, and dependence on an expensive kit of apparatus which could only be supplied while aid from UNESCO was forthcoming. In the next curricular revision, the emphasis on discovery as well as the factual overload was reduced. The NCERT curricula of the 1980s tried to combine giving information with an activity-based approach. The states are expected to produce local-level adaptations of these curricula.

One prominent effort at developing school curriculum based on the discovery approach has been the Hoshangabad Science Teaching Programme (HSTP) in Madhya Pradesh. This programme, initiated in 1972, covers rural and small town schools in some selected districts of MP. The HSTP textbooks are well designed and take careful account of the local environment. In this sense, they represent a significant improvement over the current stock of science curricula. An enquiry-oriented approach is also perhaps indispensable to offset the stifling authoritarianism of our school system. But the same approach should be used to examine curriculum innovation it-self, lest we have to choose between one dogma and another.

The author is with the Homi Bhabha Centre for Science Education, Bombay. This column appears once a month.

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FIRST PRINCIPLES

JAYASHREE RAMADAS

Of mindless pendatism

They form about a tenth of India's population and retain a treasure of indigenous knowledge, technology and art. But, in the name of planned development. We have destroyed their habitats and driven them to poverty and despair.

Indian tribals are diverse groups living in different hilly and forested regions of the country. The term "tribe" was introduced by the British and was formalized in the Indian Constitution when certain areas were declared to be "tribal areas". The importance of the tribal areas for the British government arose from their need to exploit the forests for rail-road and ship-building. The Forest Department was started in 1864, with the avowed aim of controlling the reckless felling of trees by private contractors. Soon after, the State's monopoly right over the forests was imposed. As a result, the tribals, who had for centuries enjoyed free access to natural resources, suddenly became law-breakers in their own hand.

Under the protection of the administration, traders and money-lenders established themselves in the forests. They were followed by settlers who, through outright violence, trickery and bribing of local officials, acquired legal rights to the tribals' land. The story was repeated all over India with a few exceptions, as in the North-East.

The movement to bring education to the tribals came first from the British government. It arose more as a response to the "law and order" problems in tribal areas, than from any liberal humanitarian commitments. Later, under the influence of Mahatma Gandhi, many Congress workers entered tribal villages to work towards improving their conditions. In Gujarat and Maharashtra, Gandhian social workers established Ashram schools for basic (craft-based) education. Although, the Gandhian pattern of education was not accepted in the national policy, these Ashram shalas, as public residential schools, came to form the basis of the Indian government's programme for tribal education. Residential schooling might appear to be a rather expensive proposition for mass education, but it is most appropriate in the tribal context. Besides, tribal settlements are small and scattered over large areas in hilly terrains. A school catering to several settlements requires students to travel many kilometers every day, while local single-teacher schools need to have teachers willing to commute daily to them. During the monsoons, overflowing streams and rivulets make many of the settlements completely unapproachable.

The absence of effective water-management schemes affects education in more ways than one. Tribal schools have some of the highest rates of dropout. A large part of the dropout occur in the beginning of the academic year, which happens to coincide with the peak agricultural season at the onset of the monsoons. A natural solution would be to have the schools running through the summer months, and break for vacation in the monsoons. But summer is when all the water sources dry up, forcing the residential schools to close down. Literacy in many tribal communities is as low as five percent. Economically, it makes more sense to the parents to have their children to help at home, work in the fields, collect firewood, fetch water, or take the cattle out to graze, than have them engaged in schooling which can provide only long-term and highly uncertain gains.

All this is the down side. Its consequence is that tribals are seen as disadvantaged communities in need of development, or "uplift". In schools, the performance of tribal students is markedly below that of non-tribals who might be studying in the same class. Most teachers tend to believe that these students suffer real cognitive deprivation which makes formal school subjects difficult for them to grasp.

But recently, it is being realised that tribals societies have some real strengths, in terms of extensive ecological knowledge, and customs and practices of enduring survival value. Even school students have intimate knowledge of hundreds of plant and animal species in their environment: knowledge which not only surpasses that of their teachers, but in many ways competes with what professional biologists know. The irony is that in school, this knowledge is completely ignored, and students are forced to learn a kind of biology which divorced from their own experiences. Those tribal children who manage to beat the system, do so at the expense of losing their own knowledge for a kind of superficial learning, that barely gets them the lowest-paid jobs in the hierarchy.

Research with traditional communities in India and Australia has shown that they have well-developed learning styles, different from formal learning styles expected in school. For example, learning of skills in aboriginal communities is done through observation, imitation, and practice in real situations. Complex skills like carpet weaving are transmitted through highly functional systems of encoding. The contrasting verbal, sequential, fragmented and decontextualised style of a normal school curriculum does not fit in with this traditional method.

Tribal education should, therefore, not be seen merely as one of providing a social service to a deprived and dispossessed community. Rather, it is a question of enabling the tribals, who already possess valuable knowledge, to relate to the modern world that they are increasingly coming into contact with. Their knowledge is vital not just to their own survival, but to the ecological health of the nation. It is the last remaining resource which is truly theirs, and only in their own empowerment lies its conservation.

The author is with the Homi Bhabha Centre for Science Education, Bombay. *This column appears once a month.*

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FIRST PRINCIPLES

JAYASHREE RAMADAS

Lessons in boredom

Come the new school year and students will return with an arm-load of new textbooks. They might first grab the language books, and read them through till the end. Other books may get a cursory reading, while the rest would get a bored first look, sealing their fate for the rest of the year.

Textbooks are the pivot around which revolve all aspects of school learning. The content and style of the textbook essentially determines classroom teaching, and sets the norms for examinations. It is the teacher's sole resource, particularly where libraries and laboratories do not exist.

The vast scale of textbook production in India makes it a potentially lucrative target for the private publishing industry. It also means that public debate on textbooks gets focused on their production and distribution aspects, while quality considerations are left to the authors. Nonetheless, the 1960s recommendations of the Kothari Commission to strengthen the state textbook production machinery had the salutary effect of eliminating the "textbook racket" of those days, and ensuring a (bare) minimum level of quality.

Having said that, today' Indian textbooks leave much to be desired. Take the case of science and mathematics. Despite many rounds of revisions at national and state levels, majority of books produced remain dry and uninteresting, unrelated to the lives of the students they are supposed to communicate with. It is not that good intentions are lacking. Statements of curriculum objectives, which are often quoted by textbook writers, include such laudable one as, awakening curiosity about nature, and encouraging logical thinking in children. Paradoxically, not a trace of any excitement about the subject can be gleaned from the body of the textbook.

Textbook writing committees at the national level have lately had a strong representation from prominent scientists around the country. The results, in terms of the quality of books produced, have been uneven. The contribution of even top professionals depends on the amount of time and attention that they choose to give to the job. The deceptive simplicity of the content for an expert, hides the fact that a lot of work is needed to write a good textbook.

Writers often look at school textbooks as merely diluted versions of advanced textbooks. But, books for students need to address the students' prior knowledge and spontaneously formed conceptions in the subject area, anticipating common areas of difficulty. This needs a rare sensitivity to what makes sense to students, rather that what seem like arbitrary or contrived facts. For example, the excessively formal approach adopted by most mathematics textbooks takes little cognisance of students' natural ways of thinking.

A common problem with textbooks is their lack of coherence and integration. Even concepts within a subject area are not linked together, while linkages across subject areas are practically non-existent.

In the rush to introduce a large number of concepts at an earlier stage, one sometimes loses sight of the limits set by the cognitive level of students. Abstract ideas like forces and ratios are taught without taking care to see that they are appropriate to that age-group of students, or sufficiently anchored in the concrete experiences available to them.

A major reason for the sterility of textbooks lies in the equally sterile examination system that they are tailored to. Various pressure groups of both parents and teachers have dictated that the examinations be formula-driven, totally predictable, and answerable by sheer rote learning. The textbooks therefore, emphasise definitions, questions with short, meaningless answers, and procedures that can be learnt by rote. In mathematics this has a particularly devastating effect, that problems are not seen as interesting and challenging as they could be, but as rigid procedures to be memorized.

The examination system has also had the effect that in the primary sections, facts are minimized, for fear that they will constitute a load on young minds. On the other hand, middle and secondary students are loaded with the most intricate and obscure pieces of information which presumably, are now within their capacity to memorise. Anyone who has observed young children would know that from the earliest age, they are hungry for new information about the world. The specific pieces of information are not that important: one child may be interested in knowing all about birds, while another may be interested in trains. The point is that they enjoy facts, and should be encouraged to acquire them; for facts, in later years, form the basis for abstractions. The system has to allow for this, through project work and supplementary handbooks for teachers, even though the results would not be amenable to formal examinations.

Given the reality that teachers do not have sufficient resources available to them, handbooks which suggest good teaching approaches, and give additional information, are an absolute necessity. The present teachers' handbooks merely discuss time management and order of teaching the topics, without giving any substantive ideas. Recently, the Maharashtra Bureau of Textbook Production has started to remedy the situation.

Finally, it would be well worth the cost to produce textbooks in an attractive format. The authors could lighten up a little, inject some humour, some cartoons, without necessarily talking down to students. Government subsidy or private sponsorship of better-produced books is not too much to ask for generation of better educated children.

The author is with the Homi Bhabha Centre for Science Education, Bombay. *This column appears once a month.*

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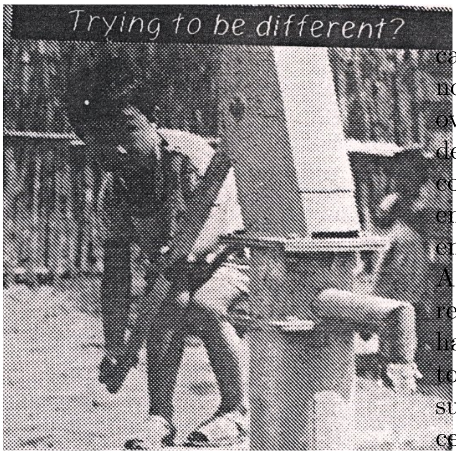
FIRST PRINCIPLES

JAYASHREE RAMADAS

No budding Einsteins here



In December 1991, when Newsweek brought out a cover story on the top ten schools in the world, they selected a Tokyo school to be the best in science teaching. “Weary of buying American ideas”, said the headline, “Japan will grow its own”.

Science education in Japan has for many years been the envy of the Western world. Japanese students ace international tests in science and mathematics, and the level of technical sophistication in the general population surpasses that anywhere else. It therefore comes as a surprise when an editorial in the Mainichi Daily News, a national newspaper in Japan, proclaims a crisis in science education. The reason for concern is a joint statement issued recently by the Japan Physical Society of Applied Physics and the Society of Physics Education, stating in effect that science education in Japan is on the verge of dying.

The indicators are many. Applicants for university science and technology faculties have been reducing over the years. Polls find that as students progress through school, they become less and less interested in science. The qualifications of university entrants have steadily deteriorated. And in an apparently retrograde move, recent revisions of school curriculum have drastically cut the time allocated to science. How does one understand such trends in the world’s most successful educational system?

During the American occupation following Japan’s defeat in World War II, the education system was completely overhauled, with the aim of removing militaristic and nationalistic tendencies. School bureaucracies are decentralised, and the curriculum restructured according to the American model. Like other such social and technological transplants, these Western ideas were deftly remoulded by the Japanese into a new distinctively indigenous system. In this system now there ius almost 100 percent literacy (in the Kanji script of more than 5000 characters!) and 94 percent of all children complete high school. The recent World Bank report has highlighted the wisdom of the Japanese policy of egalitarian co-educational schooling in the first nine years, followed by an intensely meritocratic system of higher education.

But there have been problems, the most publicised one being that of young people driven by relentless academic competition. The pressure of nationwide entrance exams of high schools and colleges takes its toll on students leading, in extreme cases, to violence and suicide. It is true that adolescents the world over are vulnerable to extreme mental tension. But when the source of tension lies within such a highly organized and controlled system, it becomes obligatory for the system to do something about it.

This the Japanese Ministry of Education has been trying: the recent curricular revisions represent an effort towards school life a little more relaxed for students. To this end, the science and social studies courses for the lower elementary grades have been integrated into a new subject, called "Daily life". And starting from Junior High School, students are offered elective courses in science and humanities.

The science faculties in universities are, however, worried that such reforms will lead to a further drift away from S & T and this worry is at the root of the joint statement by the three societies. Besides the reduction in number of students taking up S & T, there are also now few S & T graduate opting for employment in manufacturing industries. High school students who love manipulating machines and working with personal computers have been selecting humanities and social science careers; all this during a period when manufacturing industries have been at the height of prosperity! The migration of students away from S & T is therefore something of a paradox.

An interesting analysis of this phenomenon has been carried out by Prof. Shin'ichi Kobayashi of the University of Electro-communications. He considered peoples' attitude towards S & T to be a mediator between the amenities offered by S & T, and their desire to be scientists or engineers. He analysed the model empirically, using results of surveys. The model showed an increase over time in the number of people with high receptivity towards S & T products and low concern about S & T activities. This growing group of people, whom Prof. Kobayashi named "Savages in a civilized society", tend to take for granted the fruits of technology.

The technological nature of Japanese society is a mixed blessing for school education. Prof. Masakata Ogawa of the Ibaraki University says, although school students manipulate a number of gadgets, they never get to experience how such complicated mechanical things are made. Since most everyday equipments contain IC chips, their working is far from transparent; if they stop working, they have to thrown away. In elementary schools, children work with electricity sets that include small solar batteries. Such "science sets" containing standardised parts, are often used in experiments which amount to simply assembling components in a prescribed plan. Experiments using computer software translate into manipulating moving screens. Which shows how indispensable real world experiences, or, "touching, smelling and listening", are to scientific observation.

The Mainichi article also gives a bizarre story of a schoolboy who, when his pet beetle stopped moving, said, "Let's change the battery". That is a fitting parable for education, enmeshed as it is within the complex dynamics of every social system. It will not work right by simply changing the battery.

The author is with the Homi Bhabha Centre for Science Education, Bombay.