Designing and teaching appropriate technological productions with their multi-expressive and multipurpose possibilities *

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I Introduction

In technology, *Homo sapiens*, the "understander" meets *Homo faber* the "maker" and forms the powerful liaison between mind and hand. To possess technological prowess also requires a human to be a "visionary" - to imagine the impossible - and to project what may be achieved in the future based on what can be done now. Technology is about satisfying human material needs and desires.

Technology is a term variously used in English to refer to the design, process and product of modification of the environment, and the socio-cultural interactions with these. It may include the cognitive, affective and material aspects in an all-encompassing sense. Hence, using the word "technology" introduces ambiguities in a discourse. For some it may mean the application of previous knowledge to make a product, to others it may mean the knowledge about, or literacy of, procedures for making or as descriptions of products, while yet others may emphasise the aspect of skills. In as much as languages reflect people's interaction with the environment, they also reflect their technologies. That some languages do not reflect the complexity of the concept of technology must not take away from its association with the people who speak them.

From pre-history to the Space Age and beyond, all human settlements have "toyed" with technology; history of civilisations on the other hand is largely about the achievements of human groups in this area. The growing needs of humans and their quest for survival have certainly spurred the search for better ways of satisfying them, but so has basic human curiosity for new knowledge. Since the beginning of the agricultural revolution (over 10,000 years ago), humans have evolved culturally, and along with their cultures, have evolved their technologies (DeGregori, 1989; Chunawala et al, 2002).

Thus, technology's history is but a strand in the cultural history of humankind. Technology is embedded in culture and reflected in the variety of artefacts and activities, including language, of human groups. And yet, the significance of technological innovations of some cultures is less recognised than that of others at the global level. Some cultures have used technology as a tool to dominate over others. The very need to rate or assign global significance to technology, an inherently cultural component of human activities, may be questionable. However, concerns about inefficient use of resources and environmental mismanagement, has in recent times, been the focus of the discourse on the survival of human species. Nations at the receiving end of technology have been victimised in the [illegible]

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have been implicated for using "inappropriate" technologies, which have been rated using global, and hence trans-cultural, but not multi-cultural yardsticks.

India is endowed with a relatively long history of cultural evolution and early technology innovations. It is home to a vast human resource, capable of adaptive use of modern technologies, while the country has been consistently rated low on significant technological innovations (World Science Report, 1998). This apparent paradox may be resolved in as many ways as there are ideologies and their adherents. Colonisation, worldviews, social attitudes, political will and education have all been implicated for the "differential" technological performance.

Some groups lament that our school curricula give scant regard to the nation's cultural heritage of technology production and to the empowerment of its present populace with such production (Kothari, 2001). The curricula are at best aimed at the creation of a select "specialists", who can "deal" with technologies produced elsewhere. People who have historically produced local expertise to solve contextual problems are now trained by the education system to seek and adapt technologies innovated elsewhere: local producers have turned foragers in the global arena, and suppressed local production of technology.

While the causal agents may be debatable, what is incontestible is that the nation is burdened by a variety of problems, for which locally appropriate solutions must be urgently sought. Both routine problem solving and technological innovations involve multidisciplinary perspectives and multifunctional tasks. Students exposed only to narrowly defined curricular subjects as early as in elementary school, with little or no significance assigned to contextual problem solving right through school, start out with a handicap in regard to technology innovation. In a sense, they are trained to be passive recipients of technology. What is needed is to empower people of all ages to create new, locally appropriate and globally significant technology. Addressing school curricula to meet this need will not only redefine the role of education itself, it may even lead to defining a new cultural identity.

Radical as these may seem, such alternative curricular ideas have been supported by concerned educationists. Developing classroom situations that engage students in using knowledge (concepts, facts and procedures across disciplines), skills (thinking, manual and procedural and artistic skills of imaging, sketching and drawing) and values (aesthetic, social) are the final goals of a recent study undertaken at the Homi Bhabha Centre for Science Education (HBCSE). The classroom situations would generate contextual problems that encourage the use of diverse strategies to solve them. The problem being close to the real world would not only demand an interdisciplinary approach to making decisions, it would also include value judgements besides knowledge and skills. Such a learning package involving diverse, real life, need-based, goal-directed activities would be a "module". In a longer term the study may lead to the development of such "design and technology modules" for the students at the primary and middle school level.

II Metaphors of technology

Communities are powerful repositories and conveyors of meaning and serve to legitimise action. They construct and define appropriate practices. People act and construct meaning within communities of practice. In this sense, learning is seen as a dialectical process of interaction with other people, tools like language and artefacts, and the physical world. Thus, the acquisition of language and technology are both mediated by and in turn influence culture and society.

Language, technology and evolution

People learn words and the production of language in the context of communication, a fast and successful process. Apprenticeship learning of skills is its parallel in technology. The evolution of language and technology, the significant tools of culture, not only resemble human evolution, they also dynamically feed back into human evolution.

Language may be understood as a process: it is a growing corpus of words and structures, and not just sum total of what has been spoken and written. It also refers to what can be spoken and written. In that sense, it is both actual and potential. In another sense, it is a code always present among humans, and ready for individuals to use for encoding.

Human language holds the potential to continuously generate new combinations of ideas; it is open-ended. Any sentence can be a combination of words never before used together, and yet be understood by a group of listeners. It can also be used reflectively, as evidenced by the existence of this project and numerous departments of linguistics.

Tools, words and symbols are by themselves static. Humans use them and generate the dynamic processes of language and technology. For a primate, a stick has a goal in view and its usefulness ends there: say, to dig out termites. When humans have a tool, they find new uses for it, and combine it with other tools to serve new purposes. Thus technology, like language, is potentially dynamic and open-ended, and they are both inter-related. A new problem can be described using existing words in combinations (and can even create new words).

The dynamics of tool making and the evolution of language can be argued to be a function of the very evolutionary process from which humans emerged. Consider the following scenario. As a group of early hominids began using tools, they had a survival advantage, which gave rise to the evolution of groups with greater biological capacities for using tools, like a bigger area of the brain that controls the hand (or thumb). Such a population (group) had a more favourable set of tool-using traits, paving the way for improvement in tool making and hence using. Thus, the greater physiological ability for tool using together with the nature of the tool using itself led to new and improved tools. These improvements in tools and their use fed back

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interactive process continued through the evolution of humans from early hominids and beyond, until it took the open-ended form of combining tools, and became technology.

For over 30,000 years, humans have not evolved physiologically to adapt. The complex combination of humans and tool use has been a successful adaptation, allowing their spread across the globe without biological evolution. Humans had created a "cultural ecological niche" (Brace, 1967, p56). Only in this case, the technology served to adapt the environment to the organism, that is human beings. From the earliest stages of their evolution, technology and tools have involved ideas or "preconceptions" and a complex interaction between skills, ideas and materials.

Shared characteristics of language and technology

Technology and language, including words, signs and symbols share several characteristics. They are both tools of culture and located in the actions of persons and groups. They evolve when persons and groups participate in and negotiate their way through new situations. Technology, for instance, evolves in problem situations. Situations, in turn, make sense within a historical context, including the past experiences and interactions of participants, as well as anticipated actions and events. Tools and discourses, thus embody the accumulated meanings of the past: language and technology the history of a culture. They not only enable thought, intellectual processes and action, they also constrain processes and action. Language and technology thus provide a powerful means of transmitting culture. Using a language in a certain manner serves to define a person or group's identity. Using tools (and technology) in a certain manner implies adoption of a cultural belief system about how the tool is to be used. Language, artefacts and tools used are closely linked to identities and the construction of self.

Development of language and technological competence involves continued use in activity, especially in "authentic" or "real" situations, which are in contrast to "imagined" situations not in accordance with fact or reality. Communication involves making meaning in relation to the language as well as the situation, and includes words, syntax, semantics, signs and symbols, together with a related world of knowledge. Problem solving involves reasoning about purposes in relation to the resources and tools the situation affords (constraints).

Cognitive content as well as cognitive processes depend on language, artefacts and tools of the culture (Nisbett et al, 2001). Language production, meaning making, discourse, tool use and tool making are all best understood as a dynamic interplay between individuals and society at various levels of interaction.

III Cognition and culture

Some of the best minds argue that the concepts of science transcend cultures, and hence warrant uniform pedagogy. The more liberal among them even posit universal commonality of cognitive processes. The seeds of such thought are found in the works of 18th and 19th century British empiricist philosophers, including Locke, Hume and Mill. The assumption of universality is seen in the treatment of cognitive psychology by Piaget and persists to the present-day cognitive science. It has only been strengthened by the information processing model, where inferential rules and data processing procedures are equated with the universal software. The output, namely, beliefs and behaviours of different individuals can of course be different given the different inputs possible for different individuals and groups. The processes considered especially important for science and mathematics, such as categorisation, learning, inductive and deductive inference, and causal reasoning are generally presumed to be the same among all human groups.

Human cognitive processes ranging from learning abstract rule systems to categorisation have been found to be malleable enough to be affected by training (Nisbet et al, 2001). It should not come as a surprise then that members of widely different cultures socialised from birth into differing worldviews might differ even more dramatically in their cognitive processes. Recent studies have unearthed that the considerable social differences that exist among different cultures, specifically the oriental and the occidental, affect not only their beliefs about specific aspects of the world, but also their tacit epistemologies and the nature of their cognitive processes. The studies question the assumptions of universality of cognitive processes, and suggest that it is not possible to make sharp distinctions between cognitive content and cognitive processes.

Learning is situated

School education is concerned with learning and acquisition of knowledge. Whether learning is construed as active construction of concepts by students or a passive/ active transfer of information from the teacher to the taught, the school setting serves to transfer knowledge from one generation to the next. Further, this knowledge comprises abstract, decontextualised formal concepts, and is considered an integral, self-sufficient substance, independent of the situations in which it is learned and used. Hence, the context of learning is usually dominated by considerations of pedagogical utility; activity and the situation under which learning is expected to happen is given scant thought.

According to Suchman (1993, p 72) "The very premise... that schools constitute some neutral ground apart from the real world, in which things are learned that are later applied in the real world, is fundamentally misguided... All learning is learning in situ... Schools constitute a very specific situation for learning with their own cultural, historical, political, and economic interests: interests obscured by the premise that schools are a-situational. Schools prepare students not for some generic form of transfer of things learned in schools to other settings, but to be students, to succeed or to fail, to move into job markets or not, and so forth."

The context of learning, the classroom situation, is often thought to be a given in any particular educational set-up for reasons varying from a simple resistance to change in classroom settings to complex socio-economic and political forces. Besides, its efficacy in achieving stated goals or the hidden agenda of education is rarely reflected upon. However, cognitive studies in the last few decades drawing on the earlier work of Vygotsky and Piaget, and on the evidences from anthropological studies, indicate that the context of learning, including the classroom and the social setting, plays a crucial role in the acquisition of knowledge and competencies. Then there is a need to study the context of school learning and question its efficacy even for its stated goals. Important inputs for reshaping the context of learning come from studies on situated cognition.

Situated cognition (J.S. Brown 1993, Don Norman 1993) variously termed situated learning (Jean Lave, 1988, 1991) is a position that presents the acquisition of representations of knowledge, procedures and competencies as necessarily determined by the context in which they happen. Bill Clancey views representations, which include plans, formulas, algorithms and rules, as interactional. According to Clancey (1995) "Human behaviour is inherently ad hoc, inventive and unique. ...People do not simply plan and do. They continuously adjust and invent..."

Two perspectives in situated learning

Even within this tradition, there are two perspectives: one arising from anthropological studies like those of Jean Lave and Lucy Suchman (1993), and the other from cognitive scientists like J.S.Brown (1993), Bill Clancey (1995) and Don Norman (1993).

The anthropologists, who are interested in the cultural construction of meaning clarify that, "Situated ... does not imply that something is concrete and particular, or that it is not generalizable, or not imaginary. It implies that a given social practice is multiply interconnected with other aspects of ongoing social processes in activity systems at many levels of particularity and generality." (Lave, 1991) The cognitive scientists working in this area are interested in cognition at individual and social levels. They draw upon direct insights from artificial intelligence, neuroscience, linguistics and psychology to understand cognition.

Accordingly all thinking, learning and cognition are situated within particular contexts; there is no such thing as non-situated learning (Wilson and Myers, 1999). This has prompted the use of the term, *situated action*, especially among the anthropologists in cognitive science. Consider a student studying with a textbook or a computer tutor with no other people in the same room at the time. Yet, the student's activity is shaped by socio-cultural settings. This includes the social arrangements that produced the textbook or the computer program and led to the student's being enrolled in the class, where the text/ program was assigned. The culture also provided the setting in which the student's learning will make a difference in how the student participates in some social activity - a class discussion or a test.

Given these recent findings, it would be interesting to recapitulate some of the steps taken by the nation's educational bodies in addressing science and technology education in the country, specifically at school level.

IV Education and the problem of culture-specific cognition

Catering to over 150 million school going children nation-wide, and hoping to enrol yet another 35 million who are out of school, the country's education system is torn by several conflicting interests (PROBE, 1999). The national attempt to "produce a uniform level of achievement throughout the country" by providing "the same content delivered in the same way" ignores the cultural and regional diversity among Indian students and teachers. The need to promote a plurality of strategies to address the diversity of socio-cultural environments has never been more urgent or important.

The problems of mismatch between culture, educational content and pedagogy are exacerbated in the teaching of science and technology as a universal given through borrowed curricular frameworks without connections to local contexts (Chunawala et al, 1996; Natarajan et al, 1996).[1]

Defining technology and technology education

Institutions in countries around the world, engaged in dissemination of technological literacy, have defined technology in different but related ways: The USA-based International Technology Education Association (ITEA, 2000) sets the Standards for Technology Literacy (STL) as, "Technology refers to the diverse collection of processes and knowledge that people use to extend human abilities and to satisfy human needs and wants." The UNESCO glossary for "technology" elaborates the scope as, "The know-how and creative processes that may assist people utilise tools, resources and systems to solve problems and to enhance control over the natural and made environment in an endeavour to improve the human condition."

These institutions then attempt to define technology education as, "A study, which provides an opportunity for students to learn about the processes and knowledge related to technology, that are needed to solve problems and extend human capabilities."[2] A working definition of technology education derived from National Mapping Exercise in Australia reads as, "Ideas and practices developed and applied in human and environmental contexts for particular purposes through the process of designing, making and appraising."

Whatever may be the details of the definitions of technology or technology education, it is clear that technology is essentially a human activity based on "our" constant desire to improve "our" condition. It is an organised way of creating "purposeful" change. What is not so clear is whose desires, conditions and purposes are served by either technology or technology education.

Technology education in one of its earliest forms involved participating, for a livelihood, in what we call as the "crafts". While apprenticeship did not encourage innovations, where small variations were the norm, radical innovations were exceptions generated by rebels. The practice of crafts mostly involved manual activity by recipe, not by design, and suffered from a lack of superior human minds involved in its pursuit, a part of the long-standing tension between mental and manual activities. This tension plagues society and its educational systems to this day.

Science and technology in Indian school curriculum

The National Policy on Education (NPE 1968, 1986) has explicitly recognised the benefits of teaching S&T in school for individual, social and national development. In the face of increasing demand for skilled human resources, vocationalisation was advocated in [illegible] by the NCERT[3]. The new textbooks for science that follow the guidelines set by the recently drawn

[1] Findings in a 3-year study at HBCSE on "Diagnosing Learning in Primary Science" (DLIPS)
[2] ITEA, Technology for All Americans
[3] National Council for Educational Research and Training

up National Curriculum Framework (NCERT 2000) are titled "Science and Technology". The published textbooks have included elements of applications of science and technology awareness aspects scattered among concepts, processes, procedures and activities. It is heartening to note that the framework document explicitly recognises science and technology as organically linked and linked to society. Technology is narrowly defined as the "application of science" to meet human needs.

Broadly defined, technology has the potential to be a component of other existing school subjects (NCF 2000). These include subjects like "Art of Healthy and Productive Living" at the primary classes, where students are expected to engage in making clay models, painting and "design", making puppets, simple toys and "rangoli"[4]. In the upper primary (Std. VI to VIII), technology-related aspects find their place in subjects like "Work Education", which is explained as the learning of purposive and meaningful manual work resulting in useful goods, and in "Art Education", which includes aesthetic sensibility to respond to beauty in line, colour, form, movement and sound. The "Work Education" subject for higher classes translates as the introduction of pre-vocational courses for knowledge and skills to enter the world of work. These subjects have enormous potential in terms of teaching technology in context and opportunities for "design" and innovation. However, the importance accorded to them in the school (assessment), the choice of the teacher's academic background and specialisation and the lack of guidance and support to teachers all serve to make the subjects irrelevant even to school education, leave alone making it meaningful to students and society.

Integrating technology education: raising questions, seeking solutions

Should technology be clubbed with science? Science and technology share knowledge base and pedagogy. However, the implications of technology education extend beyond knowing science and scientific occupations, to vocational education and even social studies, art, ethics and value education. Clubbing technology with science will not only drain the time available for learning science, but the learning objectives of technology will also not be met.

Elements of technology in school S&T curriculum are at best being included in a piecemeal fashion. With technology being represented as application of science, the method of technology as distinct from the method of science is not even recognised. It is designed to serve the cause of technological literacy in a limited way. It does not address the innovation potential of "doing". Some alternative curricula have made serious attempts to redress this by integrating "design" and "make-it-work" activities in their curricular materials in science and other subjects[5] (Ramadas, 1998, 2001).

The NPE recommends vocationalisation of secondary education, which reflects in the curriculum as "work experience", "pre-vocational courses" and so on. Yet, vocational and polytechnic courses, at post-secondary level, garner a total enrolment of only 1.5% of the total students passing out of secondary school. Of these 50% drop out and a large fraction are

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[4] Rangoli is the art of painting designs on theground. E.g in front of homes during the festival.

[5] The Homi Bhabha Curriuculum in Primary School Science, The curricular materials of Hoshangabad Science Teaching Programme

"unemployed". This is a paradox in the face of supply falling short of skilled labour demand. The problem, among other things, lies in a lack of co-ordination between institution and industry, a low social status for such courses, which largely attract academically backward and/or economically weaker sections, inappropriate curricula, and absence of affective training for the work place.

The nation is still far from adequately training for existing technology roles at the workplace. Perhaps, it is time to redefine technology and technology education and its place in the educational process and curriculum.

Infusion of technology education without "design"

Soon after independence, India tentatively attempted and failed to implement the Gandhian ideas in education, basic education (Buniyaadi Taalim) and craft based education for self-reliance (Nayee Taalim)[6] (Gandhi, 1937, Kumar, 1995). Some of these failed attempts to integrate technology education with general education, can be explained by lack of resources, low teacher preparation and society's demand for an "academic" education. Educationally sound as it may appear to "integrate" school subjects through technology education, practical difficulties of teacher preparation, subject expertise and teacher attitudes are practical blocks.

Over the last several decades, a number of Polytechnics and Industrial Training Institutes (ITIs), besides several local non-governmental initiatives have been attempting to generate skilled human resource in the country. There are over 300 technical institutions at first-degree level, with an annual admission capacity of 65,000; about 75 polytechnics at diploma level with an annual admission capacity of 90,000. By and large, the syllabi and students are handicapped by procedural and de-contextual content, which leave no scope for design initiatives.

Higher education in technology including postgraduate and research courses (Ph.D. level) has an annual intake capacity of 11,000. Together they have contributed to making India an abundant human resource in S&T, but very low in globally rated innovations (e.g. patents). Even if one were to discount the rating, the technological prowess has not managed solve several urgent problems exemplified by droughts and other calamities caused by inefficient resource management, inferior health status and low quality of life among the majority.

The nature of technology courses in portals of learning varies from "technology for users" in school to "technology for skilled workers and supervisors" at the ITI's and Universities and "technology for entrepreneurs and academics" at the Indian Institutes of Technology and Regional Engineering Colleges. The missing aspect in all these appears to be an educational experience of "technology by design to solve a contextual problem". From technology literacy and skill-based technology education to technological capability has already been an arduous road. Nevertheless, without technological empowerment, the identity of the nation continues to be compromised.

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[6] Both proposed by M. K. Gandhi, *Buniyadee taleem* (lit. traditional education) is referred to as craft based education for self-reliance and *Nayee Taleem* (lit.new education) as "basic education".

"Design" in S&T and technical education

Design and technology (D&T) involves skills, knowledge and values. It is not only about "knowing what" or "knowing how to" as is science. People engaged in D&T concern themselves with "how to make it work" rather than "what is it?" or "how does it work?" (technology literacy), or even "what makes it work?" (science). D&T is inseparable from an end-product of its endeavour, which is "designed" to meet set goals, and "constrained" by local priorities, resources, values and skills. It involves images (as in "imagine" and sketch), symbols and models. Importantly, "technological method" is distinct from the "scientific method". Doing technology entails defining the problem, generating solution strategies (ideas), making models, applying constraints, selecting "appropriate" model, evaluating (critical thinking) and modifying the model before implementing. "Technical" education, on the other hand, is about "how it works" (not what is needed?), procedural rather than designed and low in academic content. It easily becomes obsolete, needing frequent re-skilling.

For locally appropriate technology innovation, D&T education, staring at the school level, must include aspects of knowledge, critical thinking about the activity and its consequences, sensitivity to issues and empowerment to create and to take responsibility for such creation.

Facets of technology education: multiple purposes

There are several facets to technology education at the school level. As an economic instrument, technology education contributes to national economic competitiveness and wealth creation and, in that restricted sense, is synonymous with vocational education. An appropriate education in technology is critical for sustainable development to ensure compatibility of economic growth with environmental protection. Technology education may be designed to enhance people's ability to control technology and resist the prospect of technocratic élite. It has the potential to either counter gender biases in the present-day representation of technology or, if inappropriately handled, to perpetuate them. Technology education has hitherto served to enhance the professional image of technology and engineering, improving its standing in society. An important facet of technology education is to enable people to create and control the "symbolic" world of technology.

According to Murchland (1982), "If one regards technology as a language (and not merely as a tool) and technicism as a perversion of that language, then the function of education becomes clear. For the primary task of education is to train us in the responsible use of language .... Put simply, education is what enables us to create and control the symbolic worlds, including, of course, the world of technology. That is what literacy means."

V Design and Technology: a vehicle for multiple expressions

The natural human impetus to improve life provides the "motive" for technological innovation. This suggests that human ingenuity will find a way to get something humans want badly enough, even without the scientific means. These motives of human need and aspiration, which are the real engines of technological advance, must be harnessed for the sustainable betterment of human life.

A well-planned design and technology curriculum in mixed ability and multicultural classrooms can be an inclusive rather than an exclusive endeavour - for the rich as well as the dispossessed, for those in the indigenous or the modern mould to participate in sustainable living.

(a) Technology is a task centred activity with locally/ individually negotiated goals

Any technological activity is task-centred and goal-directed and hence purposeful and focused. Whenever humans exercise their freedom and power to choose their purposes and goals, the technological tasks also become contextual and arise through human interactions with their natural and socio-cultural environments. The technology arising from contextual needs and desires has the potential to be liberating as indicated by prehistoric evolution of human existence. However, this has changed with the rise of civilisations and conquests compounded by increased social stratification and differential empowerment of communities and nation states. While the *raison d'être* of technology is to create purposeful change in the "made" world, one may well ask, echoing Marxist ideologies, "whose purpose" it is intended to serve. Clearly then, it is essential for communities to negotiate the goals of technological activities to better serve their lives and sustenance.

Technological activities in rapidly industrialising nations like India have come to be dictated by purposes from alien contexts for centuries. This has resulted in the neglect and downgrading of indigenous technologies; it has derailed the evolution and progress of local initiatives. Such nation states find themselves lagging behind in the technological "catch-up" game with the rules framed by "industrialised" societies. Nations at the receiving end of technology need to question and redefine the goals of their own technological activities, including technology education. They need to develop technological prowess within the context of local culture. While, technological activity makes use of a wide range of bodies of knowledge and skills, is not solely defined by them. Besides, design is not the prerogative of any one group of people. All cultures and groups have the capability to visualise and redesign their environment for a variety of purposes; some designs are more harmonious and aesthetic, and others more functional.

Education in design and technology can be a planned for all its participants – teachers, students and the society – to achieve locally negotiated goals.

(b) D&T involves making value choices and judgements

Design and technology involves making decisions, including which product to design and make, who it is for, what effect it will have on whom, how it will be made, what materials will be used to make it, and so on. Thus, values inform the designer and the product.

In all innovations, there are winners and losers. Technology involves changing the human-made world in ways that could benefit some and could harm others. Sometimes it may be a compromise, with the winners themselves losing a little. At times, the physical environment and its resources may be compromised. It is important that all people learn to integrate within the technological activities of their community, those values that ensure the sustainability of local resources. They may also become better able to judge the appropriateness of existing technologies.

(c) Technology activity is not merely applied science

A traditional view says that technology is driven by science. But historically, technology has often led science. The history of science is replete with such examples. Chinese had fireworks rockets before there was a theory of rocket propulsion. A functioning steam engine preceded the Laws of Thermodynamics. Bell's telephone system depended on the electrical properties of carbon then unknown.

Science can provide the resources/ means for technological advances. Knowledge and excellence in science, however, are not sufficient or even necessary conditions for technological innovation. India, which is proud of a scientific human resource, is found wanting not only in terms of documented innovations, but also in terms of a better quality of life for the people. To some, the situation may seem ironical for a country with a rich legacy of innovative practices. Others may argue that such nations have not yet grasped the language of modern technology. A D&T education needs to include a metaphoric understanding of technological activities for all people, not only the practitioners and professionals. This is briefly discussed in a later section.

(d) Design and technology uses a shared language of words, signs and symbols

External representations seem to play a special role in internal cognition (ref: Langer, 1962; Vygotsky, 1966). This explains the extended use of diagrams, tallies, writing and mathematics. Cultures are bounteous providers of such external representations or "packaged concepts". They have local computational advantages and have been used for design and technology activities in all cultures for centuries. The history of engineering drawings demonstrates that the modelling methods available to designers do directly affect the potential content of their thoughts (Baynes 1992). Design and technology activities provide the discourse space and cultural environment that support the use and learning of technology-specific language.

As do several domains of specialisation like physics, biology and economics, design and technology too uses a language shared by the practitioners within this domain. Activities in this domain involve description through technical terms, using images and symbols, through sketching, technical drawing, diagrams and photographs. The language of design and technology is concrete: imagining, drawing and making models. Signs and symbols are used for representing an idea, modifying it and communicating with peers. This has been an under-rated subject in Indian school curriculum. It has at best been addressed in the art or craft class, which has so far been given very little importance relative to other subjects in the school curriculum, and plays a negligible role beyond the primary stages. The reasons for the situation lie within and beyond the curriculum itself, in teacher attitudes, parental concerns and the society itself.

VI Technology understanding versus capability: multi-lingualism revisited

Consider the following rephrased version of Langer's (1962) original quote on language and thought: *Images are our prime instrument of technological expression. The things we draw are in effect the things we can think. Models are the terms of our thinking as well as the terms in which we present our thoughts, because they present the objects of thought to the thinker himself. Before a drawing communicated ideas, it gives them form, makes them clear and in fact makes them what they are.* (Kimbell et al, 1996)

It is clear that a concrete language is essential to technological innovations. However, it is the proficiency in such a language that will determine its use for technological development. As quoted in Kimbell at al (1996), there is a critical and recursive (iterative) relationship between expression of ideas and the development of ideas among novice technology students in school. "*... the act of expression pushes ideas forward. By the same token, the additional clarity that this throws on the idea enables the originator to think more deeply about it, which further extends the possibilities in the idea. Concrete expression (by whatever man) is therefore not merely something that allows to see the designer's ideas, it is something without which the designer is unable to be clear what the ideas are.*"

It might be argued that technology education in school could merely provide students the opportunities for learning the language of design and technology through cognitive modelling. This would involve reading about the ideas in technological artefacts and writing about it, perhaps with helpful diagrams and sketches. One might even question its validity in ensuring technological literacy, for it has severe limitations when it comes to complex ideas and patterns. It is only through the expression of these in the form of models and drawings that the ideas can be clarified.

Teaching design and technology to primary and pre-school students, like play, can help to promote creative, critical and playful thinking by helping children to internalise and develop their imagination. The development of imagination is dependent on learning to use tools of thought, and these tools evolve as they are used in playful, innovative ways (Parker-Rees, 1997; Senesi, 1998, 1998a, 2000, 2000a).

Just as the existence of a language is no guarantee of its fluent use, a complex language of technology at people's disposal is no guarantee of its creative use. There is a world of difference between using the language to understand and respond, and using it to create new technology. The latter calls for a much higher level of sophistication in the use of language, besides a sense of ownership over the language of technology. In this sense, it parallels the problems of multilingual education. In fact, in the multi-cultural settings prevalent in India, the language of technology can potentially evolve within the classrooms. Its evolution will be negotiated by the taught, with culture-sensitive teachers capable of evolving "appropriate" technical vocabulary.

Design and Technology: a multidisciplinary teaching perspective

To acquire capability in design and technology pupils need to master the knowledge and understanding not only of key concepts within the ambit of technology (like "mechanisms" and "product quality"), but also concepts from other disciplines, such as science (electricity), or art (use of 'visual elements'). They must also have the ability to combine these within a design task by employing a range of process skills. Procedural ability will include an understanding of how to go about designing and making and will include process skills such as specifying outcomes, modelling ideas and evaluating products.

Contextual answers must be sought for several questions before D&T can serve to empower rather than exclude students, and citizens, from participation in the technological endeavour. For one, the level of school education (pre-school to secondary) at which D&T should be introduced needs to be discussed, along with the nature of its content and pedagogy at each level. The proven potential of appropriately taught design and technology to enhance the learning of other subjects will go a long way to support its introduction as a school subject. Its potential for integration with other existing subjects also needs probing. Considering the large numbers of both students and teachers in the Indian educational system, methods need to be worked out to orient teachers to best teach for design and technology capability (going beyond technological literacy). This must be done keeping in view the history of educational practices. The socio-cultural differences in the practice of design and technology and the ideologies of equity need to be clearly spelt out and incorporated in the planning of school curricula.

A few of these issues, especially pertaining to curricular integration and socio-cultural differences will be probed through an action-research project in schools in and around the city of Mumbai. Some of the deeper issues will need continued research in the area.

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