INVESTIGATING MIDDLE SCHOOL STUDENTS' PERCEPTIONS OF TECHNOLOGY AND DEVELOPING DESIGN AND TECHNOLOGY EDUCATION UNITS TO STUDY STUDENTS' DESIGN PRODUCTIONS

A Thesis

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by

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DECLARATION

This thesis is a presentation of my original research work. Wherever contributions of others are involved, every effort is made to indicate this clearly, with due reference to the literature, and acknowledgement of collaborative research and discussions.

The work was done under the guidance of Professor Chitra Natarajan, at the Tata Institute of Fundamental Research, Mumbai.

Ritesh P. Khunyakari

In my capacity as supervisor of the candidate's thesis, I certify that the above statements are true to the best of my knowledge.

Chitra Natarajan

Date:

Dedicated to the memories of

my father
Late Shri. P. C. Khunyakari
and
my brother
Late Shri. Rupesh P. Khunyakari

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Chapter 1

Introduction

This chapter gives an overview of the factors that motivated this research, the problem statement, the research objectives and a brief idea of the content of this thesis. The methodological standpoint that guided the study is explained, followed by the organisation of the thesis.

1.1 Background for the study

Technology influences us in many different ways. Artefacts that surround us and with which we interact are the first impressions of a technological world. However, people often fail to see technology beyond artefacts. Such a perception of the technological world limits us to mere users, allowing little freedom to utilize our skills and capabilities as technology creators and decision makers.

Broadening ideas about technology

Literature on attitudes towards technology reveal that a majority of people have a narrow conception of technology as involving computers, machines and modern age (post-industrial) products. Positive attitudes towards technology and exposure to technological engagements of different kinds may help create critical, active and empowered innovators of technologies.

Technology is sometimes identified with only its technical aspects, with cultural values and organisational factors being regarded as external to technology. However, technological practices involve the technical, organisational as well as the cultural aspects (Pacey 1983) and they often involve groups of people working in collaboration. Many of the current learning practices in schools emphasize activities for individuals and rarely accommodate a collaborative activity. We propose that suitable technological activities may help students to appreciate the technological process as well as realise the benefits of team-work. Besides, such engagements may mediate a change in students' perceptions from technology as specialised activities located in "high tech" centres to everyday technologies that involve creative foresight, mental visualisation, and manipulations, which allow pre-planned modifications of the environment.

Integrating contextual meanings of technology

The contextual nature of technology is evident in the multiple meanings associated with the term *technology*. Most scientists and science educators limit the meaning of *technology* to applied science. For them, teaching science adequately prepares students for doing technology. Technology educators often see technology as a vocational subject. There are yet others who relate technology with the crafts. Art and craft in school would for them, prepare students for engaging with technology. In each of these interpretations, some elements of technology activity are obscured. The approaches for teaching technology may convey a limited perception of technology. So what could be a broader and an encompassing conception of technology?

Philosophers have long argued about ways of characterising and defining the nature of technology. One of the useful ways of understanding the nature of technology is in terms of its four manifestations suggested by Carl Mitcham (1994): as artefacts, processes, knowledge and volition. Philosophical debates on the nature of technology or issues that pertain to the methodology (process) of technology give valuable insights about perceptions of and practices in technology. What seems to be clear is that technology transcends the boundaries of the disciplines of the sciences and the arts.

Transcending disciplinary boundaries

The systems of formal learning which follow a "disciplinary" approach, tend to compartmentalise concepts and praxis. Curricular subjects in school education include little of problem solving. Technology problems, on the other hand, cuts across disciplines and calls for integration of knowledge and skills from several domains of human activity. Any technological activity draws from a range of specific knowledge, skills and values to meet a contextual need. Hence, technology activities can provide authentic contexts for learning and using knowledge and skills, which are meaningful contexts than those provided by the fragmented disciplines (Benenson 2001). Besides providing a context for integrating and practising skills and concepts learned in school subjects, it has other intrinsic benefits.

Educational benefits of working with hands

Central to teaching technology is the role of "working with hands". Formal institutionalised education placed the conceptual understanding on a high pedestal with a consequent neglect of the practical aspects in learning. However, the significant role of *working with hands* in cognition has been stressed time and again by educational philosophers and social reformers. Important insights have been provided by the works of Jean Piaget, Lev Vygotsky, John Dewey and David Kolb who emphasized the role of mind-hand co-ordination in the cognitive development of an individual.

Among the local efforts, Indian social reformers such as Mahatma Gandhi, Rabindranath Tagore and Sister Nivedita made efforts towards integrating practical aspects of learning and doing (Gandhi 1945, Nivedita 2001). In recent years, it has been shown that the development of children proceeds from a 'Let's do it and see if it works' approach to an appreciation for the hypothetico-deductive method to an understanding of the role of experiments in science (Schauble, Klopfer and Raghavan 1991, Ramadas, Natarajan, Chunawala and Apte 1996). Thus, *working with hands* is a crucial element of an individual's development. Other benefits also form an important basis for undertaking the study.

D&T education: a vehicle for multiple expressions

School learning emphasizes verbal modes of expression. Learning in a non-native language, such as English, poses serious constraints on Indian students' thoughts and ideas – the crucial ingredients of active learning. The classroom communication is severely constrained by content and language of the textbooks. This education alienates a majority of students from their environments, suppresses their natural and culturally rich modes of expression and in several culturally rich regions stifles local technological innovations.

Technology education is not just a way of integrating ideas but a means of valuing the components of learning that go into the overall development of an individual. Design, an essential component of any technological activity, involves negotiation of the problem, considerations of constraints and resources, visualisation of an anticipated artefact as a solution to the problem at hand and making decisions. The language of Design and Technology (D&T) is more inclusive: it includes a range of non-verbal modes of thought and communication: images and symbols, sketches, technical drawings, diagrams, gestures, photographs and models. D&T activities provide the discourse space and cultural environment that support a variety of learning and expression (Natarajan 2004).

Towards an inclusive endeavour

Technology is context dependent in its meaning. However, technology education needs to be suitable for school girls and boys coming from different socio-cultural (urban and rural) and linguistic backgrounds. 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. Collaborative modes of working facilitate exchange of ideas and resources among peers, and build rapport between the teacher and the learner. Besides, rules of thumb, implicit practices and nuances of material and resource handling are acquired by being in such an engagement.

Cognition in technology education

There are some gaps in research in the area of technology education. The present study attempted to address some of these gaps. Research in technology education lacks a coherent focus and direction, especially with regard to cognition and learning (Zuga 2004). She diagnosed this to be a result of low number of active researchers, complacent attitude in working with little data, collective opinions and prescriptive content, absence of a theoretical perspective guiding research and lack of clear content, as reasons for the problem. Zuga suggests that observations of student engagements can give valuable insights of ideas and concepts that students use and learn, and how they learn. She emphasizes the need for action research guided by a theoretical perspective and identifying constructs and concepts that are to be learnt through a technological activity.

De Miranda (2004) advocates grounding the teaching of technology in the well-researched tradition of cognitive sciences. According to him, cognitive models of learning and instruction allow for active roles to both teacher as well as the learner and are critical to bridging the gap between theory and practice. In the learning process, the student reflects, monitors, evaluates and engages in self-regulation while the teacher is a facilitator, who helps students and provides opportunities for engagement and expression.

1.2 Motivation for the study

Technology education as a subject, does not exist in the present Indian school curricula. The potentials of D&T education, which have been discussed in the earlier section, provided the necessary trigger to pursue this research. What could be the nature of a contextually valid unit for engaging students in design and technology? To address this larger question, it was crucial to understand the meanings and associations that students make with the term *technology*. Understanding students' ideas is a key step towards meaningful learning. Insights gained from the survey would help make decisions of the choice of units and the structure and content of the units. The units derived from such an understanding needed to be tested in the Indian settings. Literature suggests that diverse approaches have been used for teaching technology in several countries of the world. What could be an appropriate pedagogical approach for the Indian context? Do the units designed appropriately engage students in cognitively challenging situations? Analysis of classroom observations can give insights into the aspects of design and cognition in the classroom. Students' design productions generated during their engagement in the D&T education units could serve as sources for studying students' cognitive activity. All these concerns formed the basis for the research study.

1.3 The study

The research and development initiative at the Homi Bhabha Centre for Science Education (HBCSE) began with a survey of ideas about technology among Class 8 (age 13 years) students. A questionnaire developed for the purpose was administered to students in urban and rural settings and those coming from English and Marathi medium schools in and around Mumbai. Building on insights from the survey and an understanding of issues in philosophy of technology and technology education, three D&T education units were developed through trials that engaged students in designing and making artefacts or systems. Trials of the three units were conducted in three schools with different socio-cultural and linguistic environments. Student interactions in the classroom trials and their design productions were studied for aspects of cognition. Insights into the cognitive aspects of the D&T units has been the core component of this study. The study to our knowledge, the first of its kind in the context studied, is a baseline investigation that would be helpful in garnering ideas and insights for developing a technology education curricula suitable for the urban and rural settings in India.

1.4 Statement of the problem

The work reported here is about developing Design and Technology (D&T) education units suitable for Indian middle school students, conducting trials in urban and rural settings and analyzing the cognitive aspects in students' productions. The development was guided by the results of a probe study on students' perceptions about technology.

1.5 Research objectives

The research study had three specific objectives:

- To study middle school students' (age 13 years) ideas about technology by developing a survey questionnaire for the purpose and administering it to Class 8 students from urban and rural schools in and around Mumbai.
- To develop D&T education units through classroom trials among students from urban and rural middle schools with English and Marathi medium of learning.
- To analyse the trials of D&T education units for content and pedagogic aspects in classroom observations, and for cognitive aspects in students' design productions.

1.6 Operationalising terms used

Unit: consists of group of tasks or activities, unified by a common theme and purpose, sequentially structured towards designing and actualising an artefact or system by collaborative participation of students, teachers and experts. The tasks are set in contexts and engage the students in acquiring knowledge and skills and discussing values.

Middle school students: In the formal system of school education, students studying in classes six to eight, are called middle school students. Typically, they are in the age range 11 to 15 years.

Design productions: Drawings produced during the designing activity are a window to students' evolving thoughts and ideas. These are produced for the intent to make rather than serve as 'finished product' (Hope 2000). For the purpose of this research, design productions in the context of D&T education units are of 3 kinds: exploratory sketches, technical drawings and procedural map. Characteristics and role of design productions in D&T units are discussed in Chapter 4.

1.7 The methodological stance

The methodological stance explains why we needed to blend different research designs and the outcomes we harnessed from such a fusion. The aim of the research study being development of educational units in a subject not existing in Indian schools, through an exploratory perspective, the research paradigm may best be described as developmental exploratory.

The research study reported is exploratory in nature for two reasons. First, the nascent field of Design and Technology (D&T) education, unlike other disciplines of study such as the sciences and the humanities, does not have a precedence of rich research and unique established content. There are no established models or a singular theory for basing our research. Second, the intention of the study is to arrive at a model for teaching technology to Indian middle school students, appropriate in terms of its content, pedagogy and measures of assessment. The entire process of development through trials is an evolving one and hence connotes an exploratory research paradigm. Exploratory research provides the flexibility to study different facets of a problem as they come along in the course of research. Such studies strive to discover ideas and gain insights (Kothari 2005).

The visual model for exploratory research in Figure 1.1 (Routio 2007) illustrates the nature of interaction between the object of study in the empirical world (empiria) and the conceptual world (theory). In contrast to the generic research design depicted in Figure 1.1(a), the exploratory research design in Figure 1.1(b) lacks a unique or accepted theoretical model for the context studied (as indicated with dotted lines), which is developed during the course of research. Our research evolved from a preliminary to a deeper understanding of technology education in Indian classroom with synthesis of ideas from philosophy of technology and other relevant literature in the field, much akin to the model of exploratory research indicated in Figure 1.1. The three objects of our study may be considered as our three research objectives, namely; students' attitudes towards technology, developing a suitable pedagogy for teaching technology to Indian middle school students, and gaining insights into cognitive aspects of D&T units. Through engaging in a developmental exploratory research a possible model valid for teaching technology in the Indian classrooms has been arrived at. The pedagogical model is discussed in detail in Chapter 4.

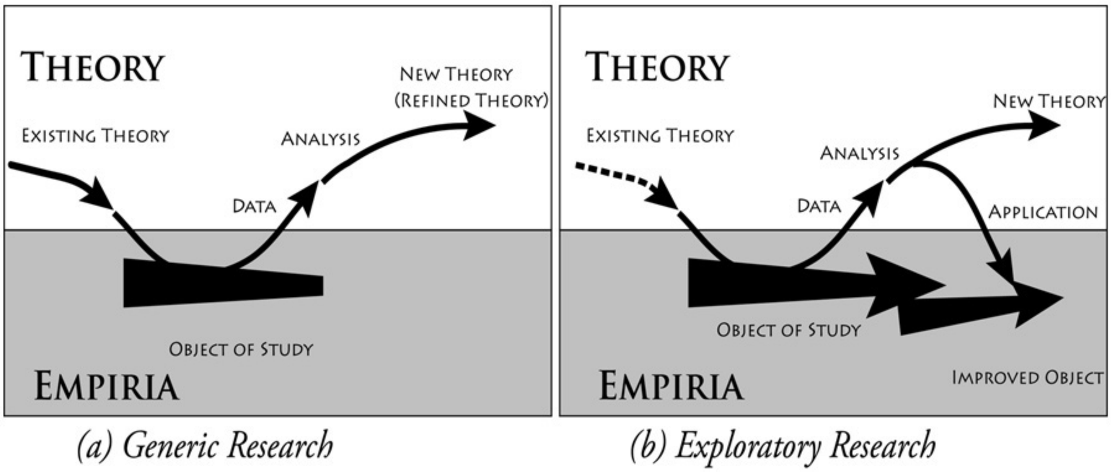


Fig. 1.1: Visual depiction of model explaining the process in exploratory research. Adapted from Routio (2007).

The entire study sought to strike a balance between the relevant theoretical viewpoints and empirical insights. Survey instrument designed integrated ideas from the philosophy of technology and the empirical insights from an earlier study that had probed students' images of technology using posters as a medium of expression (Mehrotra, Khunyakari, Chunawala and Natarajan 2003). The survey was followed by development of D&T units suitable for urban and rural middle school students. The conceptual framework that informed development of units was again a blend of ideas from theories of learning, literature on design and cognition and empirical work in the field carried out in different contexts. Thus, all through this study, the methodological stance aimed at marrying theoretical foundations from literature and insights from our empirical work.

1.8 Scope and significance of the research

Though limited in its scope on certain issues, the study nevertheless has been a first step towards an attempt to integrate D&T education in the Indian schools. It is also hoped that this study with the Indian middle school students would give valuable insights into the cognitive aspects in D&T education and that learnings in the Indian context may also inform the teaching practices and contribute to the growing field of technology education.

Survey involved a structured instrument which probed students' responses from a large sample of class 8 students (average age 13 years) representing urban and rural (tribal) settings coming from schools with English or Marathi medium of learning. The exploration helped us see whether urban and rural, English and Marathi, and girls and boys perceived technology differently. Knowing students' perceptions can help prepare the teachers and curriculum designers, like the researcher in this study, to tailor units which are inclusive and have a potential for broadening students' understanding of technology. Survey using a large student sample is better suited for generalisation. However, the reason that underlies the response to an item remains concealed and can only be uncovered through focused interviews. This survey inspired another study by my colleague with Class 6 students in which administration of a short questionnaire was followed by detailed interviews of a few students among those surveyed and has been reported elsewhere (Mehrotra, Khunyakari, Chunawala and Natarajan 2007).

The developmental exploratory nature of research helped evolve ideas through the trials of the D&T units. The content and pedagogy of the unit got refined and validated through the trials in the three distinct settings, namely, an Urban Marathi medium, an Urban English medium and a Rural Marathi medium school. The units provide scope for contextualising learning through an integration of concepts and skills necessary in a collaborative design problem situation. The study gave valuable insights about the benefits of engaging students in D&T education. The units gave a first-hand experience of integrating the non-formal modes of communication; aspects of designing, planning and making activities; collaborative modes of working; decision-making and peer evaluation.

Analysis of the D&T units gave empirical evidences of how students in different settings react to design and make situations. Classroom observations revealed the cognitive activities that happen during interactions in a collaborative environment and how it shaped the learning experience. The thrust of this study were the evidences of cognition studied using students' design productions, which served as a window to the process of designing rather than a finished product. Qualitative comparisons across the three settings and the three units helped us appreciate the diversity and richness of ideas that emerged through students' engagement in designing. The differences in productions in the three units indicated to a number of factors that play an important role in design and make tasks. Besides, design explorations have opened up several possible areas of study like the role of gestures in designing and making activities among naïve designers, the influence of visual and conceptual analogies and the influence of prior exposure to mechanisms and principles in design.

Assessment of students' activities, a critical and difficult aspect of introducing D&T education as a school subject, needs to be devised and studied. A subset of a classroom participated in the trials carried out by a team of 4 researchers. The units need to be tested in a full-size classroom with one or two teachers. The teacher professional background that will best facilitate D&T education needs to be probed. In addition, a study of naïve, novice and expert designers will help understand cognitive aspects of design better.

1.9 Organisation of the thesis

The current chapter has introduced the research study reported in this thesis. Beginning with the background and motivation for the research, the chapter outlined the purpose, the research questions and the methodological stance that guided the study. Subsequent chapters dwell on several aspects of the research undertaken.

The second chapter reviews the literature in the field of technology education relevant to the current study. It includes insights from survey studies on perceptions of and attitudes towards technology in several countries across the globe, including those in India and discusses issues and concerns pertaining to teaching technology in schools. Conceptualising D&T units requires addressing students' ideas about technology and aspects influencing the development and trials of D&T units in order to judge their suitability for a context. The chapter provides a basis for analysing the aspects discussed in the research study in its different phases.

Among the several phases, the first was a survey of students' ideas about technology using a questionnaire survey. Chapter 3 discusses the development of questionnaire, its administration, analysis of students' responses and the findings of the survey. The survey involved Class 8 students (age 13 years) from urban and rural schools with Marathi or English as the medium of instruction in schools. The survey methodology included development of a suitable instrument, choice of sample for study, pilot testing, reliability and validation of the instrument, and data collection for the final survey. Framework used for analysing students' responses, analysis and findings of the survey are also reported in the chapter.

Building on the insights from the survey results and considering the numerous aspects for teaching technology, Chapter 4 deals with the development of the D&T units that evolved through feedback from the trials. The chapter discusses the sample, the development-trial iteration, and data collection. The path followed in developing the three D&T units is discussed in terms of the six aspects identified as crucial to teaching technology. Learnings from the trials of the units for each of the units are discussed in depth. The experience of development through trials helped evolve a pedagogic model for teaching technology to Indian middle school students.

Chapter 5 discusses the analysis of design productions, which were outcomes of the different phases of designing and making activities. A framework was developed for analysing classroom observations which give analytical insights into the development of units. The salient results of classroom observations are followed by a framework developed for analysing students' design productions and the findings so obtained. Analysis of these productions gave valuable insights on how each unit was received by the students and how they progressed through the three units. Besides, the units developed have emerged as exemplars for designing and carrying out teaching practices in technology education, a new subject in the Indian context.

Insights gained from the discussion in each of the previous chapters are woven together to get a feel of the larger picture that has emerged from the several facets of this study. The concluding chapter summarizes the findings of the survey study, development and trials and the cognitive aspects revealed through students' design productions. Implications of the findings for education in general, and technology education in particular, are foreseen. Finally, some leads for future research are also presented.

Chapter 2

Literature review on Technology Education

This chapter begins with a discussion on technology, which includes an attempt to characterise technology. The role of technology in education and its place in school curricula is presented followed by a discussion on technology in the Indian context and an overview of literature on students' ideas about technology. Concerns and issues in the introduction of technology education are presented followed by aspects of design cognition in technology engagements. The last section summarises the issues pertaining to technology education that have been considered in the research study reported here.

2.1 Understanding technology

Technology is useful not just for meeting the basic human needs of food, clothing and shelter, but also in satisfying human desires of aesthetics and creativity. For example, building a house is as much about human ingenuity in its design and construction as about the preferences of its layout and details.

Technologies have brought about major changes in the social and economic structure of our society. Lawson (2006) observes that the technological developments in the twentieth century are so rapid, that for the first time in human history, we can evidence a change palpable within a single lifetime. Interestingly however, there is a paradox. Even as technology has become increasingly important in our lives, it has receded from our view. Pearson and Young (2002) note that although our use of technology is increasing, there is no sign of a corresponding improvement in our ability to deal with the issues relating to technology.

Education lays the foundation for an individual's development as an informed citizen. Not all pupils will become practising technologists but all may face technology-related dilemmas during their lifetimes. Future citizens should not only have the skills to use technology in a safe and proper way, but also know how technology is developed, what decisions are made in that process, and what roles they can play in influencing those decisions (de Vries 2002, p288). In other words, citizens ought to have an understanding of what technology is.

2.1.1 Technology: meanings and interpretations

The term *technology* is derived from the two Greek words: *techne* and *logos*. *Techne*, commonly translated as "art", "craft", or "skill", which stems from an Indo-European root *tekhn-*, probably meaning "woodwork" or "carpentry", and is akin to the Greek *tekton* and Sanskrit *taksan*, meaning a "carpenter" or "builder", and the Sanskrit *taksati*, "he forms","constructs", or "builds", whereas *logos* means rational principle (Mitcham 1994). The diverse meanings of the term *technology* indicate the rich meanings associated with the term.

It is acknowledged that technology is a *slippery* term that may trigger multiple meanings in diverse contexts of its use (MacKenzie and Wajcman 2002). Attempts to define technology in recent years has elicited much effort but little consensus among experts. While some prefer overarching and comprehensive definitions of technology, others strive to delimit the definition to allow meaningful academic discussions. It would therefore be useful to consider a few definitions to get an idea of the diverse meanings about technology. The Cowles Encyclopedia of Science, Industry and Technology (Berkner and Kranzberg 1969), defines technology as

> ...the human development of any aid - physical or intellectual - in generating structures, products, or services that can increase [hu]man's pro-

> ductivity through better understanding, adaptation to, and control of, his[/her] environment.

This definition focuses on efficiency and control, unlike the more recent definitions in the educational contexts. The Standards for Technological Literacy (ITEA 2007) document highlights "human needs and wants" in defining technology as:

> . . . the diverse collection of processes and knowledge that people use to extend human abilities and to satisfy human needs and wants

Thus, technology is recognised to depend on humans and their contexts, which could be quite diverse. Yet, another definition emphasizes the role of processes and systems (Pearson and Young 2002, p13).

> Technology comprises the entire system of people and organizations, knowledge, processes, and devices that go into creating and operating technological artifacts, as well as the artifacts themselves.

Application of knowledge to practical tasks has been emphasized in a definition by Naughton (1994, p12).

> Technology is the application of scientific and other knowledge (gained from experience, craft, apprenticeship and other sources) to practical tasks by organisations that involve people and machines.

The UNESCO glossary defines technology in a very broad sense referring it to 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.

Technology, especially in school textbooks and popular writing, is confused with science, and the words "science" and "technology" are used interchangeably (Sismondo

2004). It is no surprise that the emergent discipline of technology education has also not escaped the impact of such contextual meanings and has been variously interpreted as applied science, as technical and vocational education, as educational technology or as information and communications technology. The way in which technology is represented in education has a crucial effect on people's understanding of and their relationship with technology. A clearer understanding of the nature of technology is therefore necessary for making teaching and learning meaningful. Perhaps, characterising rather than defining technology, as in the domain of philosophy of technology, is a potentially viable solution to understand what the term implies.

2.1.2 Technology through a philosophical perspective

According to de Vries (2005), turning to the discipline of philosophy of technology may be insightful for the two significant functions that it serves, namely; analytical and critical. In the *analytical* sense, philosophy helps us to conceptualize by resolving dead-ends in debates, especially when they are caused by the naïve use of terms. While the *critical* function of philosophy helps us reflect and make value judgements. The notion can be extrapolated to explain our understanding of technology in terms of viewpoints.

From an analytical viewpoint, Mitcham (1994) has provided a useful characterisation of technology in terms of its four manifestations; technology as: objects (includes material objects and tools), knowledge (recipes, rules, theories, intuitive "know-how"), activities (design, construction, use, etc.) and volition (knowing how to use technology and understanding its consequences for an individual as well as for the society).

From a critical viewpoint, philosophy offers a good ground for discussing the manifestations of technology. De Vries (2005) demonstrated this by mapping the manifestations of technology proposed by Mitcham onto the fields of intellectual discourse known in philosophy (see Table 2.1).

Further, he outlines the role of philosophy for technology education as: (1) a source of inspiration for determining the content of a curriculum, (2) a conceptual basis for understanding technology that can help technology educators respond to unforeseen situations while teaching about technology, (3) helping position the teaching

Table 2.1: Mapping manifestations of technology with fields in philosophy

Manifestations of technology	**Fields in Philosophy**
Technology as Objects (Artefacts)	Ontology
Technology as Knowledge	Epistemology
Technology as Activities (Actions)	Methodology
Technology as Volition	Teleology, Ethics and Aesthetics

of technology among other subjects, and (4) helping identify agendas for research in technology education, thus building a link between educational research and practice.

This understanding is central to equipping future citizens with the skills and competencies to carve a productive and sustainable technological niche. In order to achieve this goal, it is essential to first examine the role of technology in school education. An understanding of philosophy of technology needs to guide the efforts in developing technology education curricula and teacher preparation.

2.2 Technology and school education

One of the fundamental characteristics that distinguishes humans from other living kinds is the capacity to learn and respond rather than react by instinct. Education is a process involving deliberate organized instruction with the aim of transmitting cultural values (Chunawala 2004). This process invariably bears the influence of philosophies and ideologies as well as the goals of the society. The place of technology in school curricula, identification of the stakeholders in technology education and the diverse approaches to technology education across the globe, indicate contextual and socio-historical ideas held in different communities of people.

Technology education, an emerging discipline, does not have a recent history and a tradition as a component of general education (Layton 1994). Very often technology education is confused with educational technology, applied science, art and craft, vocational and technical education, engineering education or industrial arts. This comes out vividly when one compares the plural approaches to technology education across the globe (see section 2.2.1). It is hard to miss the fact that each of these approaches have been influenced by what the nation expects from its educational system. A number of local stakeholders influence the curricula. The stakeholders identified by Layton (1993), who influence the nature of a curriculum have been briefly described below.

Economic instrumentalists: For people who view education as an instrument for building national economic competitiveness and for creating wealth, technology education is synonymous with vocational education.

Professional technologists: They have an underlying concern for improving the standing of engineering in society and emphasize the need for including basic knowledge and construction relevant skills in school curriculum.

Sustainable developers: Their concern is to empower people with knowledge, skills and values needed to control technological developments in order to maintain a balance between economic growth and environmental protection.

Defenders of gender equity: They emphasize the need to especially enable girls to define technological challenges, and respond to them in their own terms.

Defenders of participatory democracy: They encourage equitable access to technology for all citizens to enhance people's ability to control technology.

Liberal educators: For these stakeholders, technological activity involves a distinctive form of cognition, unique and irreducible, and hence an essential component of the school curriculum.

2.2.1 Technology education across the globe

Technology education as a discipline has evolved through a process of subject transformation and through the influence of subject antecedents (Layton 1993). De Vries (1994) has described 8 curricular approaches to technology education. Predominance of a particular feature or a combination of features characterises an approach as a distinct one. The following 7 features form the basis for the categorisation.

1. **Goals:** These may be set or stated in terms of curricular targets or learner competencies. For example, the goal may be to achieve efficient bulk production and generate skilled labour force.

2. **Nature of students' activities:** This feature describes the kind of activities that are focussed in the curricula. For example, a curricular approach may emphasize craft-oriented *making abilities*.

3. **Classroom organisation and equipment:** The availability of classroom resources, and its organisation reflect the curricular approach.

4. **Teacher background and orientation:** The academic and professional background of the teacher influence the goals of technology education transacted in the classroom.

5. **Stimulations from social contexts:** A strong social need may drive the goals of a technology curriculum.

6. **Gender aspects:** This feature of a curriculum indicates the extent of discrimination in the content and access to technology education within the curricular approach.

7. **Acquired concept of technology:** Learner's knowledge about and understanding of technology are influenced by the curricular approach followed.

Table 2.2 summarizes the diverse approaches, and their salient features with a few examples of countries adopting the approaches. In some cases, a country follows more than one approach. Most developments related to integrating technology education in schools have been initiated at the secondary level, where external influences or stakeholders for reform bear strongly and where subject precursors are more obvious. However, there are strong proponents who emphasize the need to introduce technology education at the primary level as well. These diverse interests underlie the motives for developing technology education as a discipline. However, national curricula need to address issues raised by all the stakeholders to a lesser or greater extent. An overview of the approaches to technology education across the globe indicates this. Where does India figure on the global canvas of the diverse approaches to technology education? The place of technology in the Indian curricula is addressed in the next section.

Table 2.2: Summary of approaches to technology education across the globe, based on de Vries (1994).

Approaches	Goals	Activity	Organisation	Teacher Education	Social context	Gender	Acquired concept	Examples
Craft-oriented	Enhance making skills	Making	Machines and tools	Craft or Technical	Skilled workers	Almost no females	Making things	Belgium, the Netherlands, Germany
Industry-oriented	Efficient bulk production	Procedural production	Industrial equipments	Trained in industries	Trained workforce	More males, less females	Bulk production	Germany, France, Japan
High-tech	Using sophisticated artefacts	Production, Simulations	Sophisticated instruments, Computers	Equipment handling and use	Possession, know-how, economic superiority	Males and females	Production	Germany, USA, Japan
Science-oriented or applied science	Science for all	Application of scientific laws and principles	Science classroom	Science	Application of science knowledge	More males, less females	Applied Sciences	China, USA
Engineering or general technological	Understand technological designs	Model making, product analysis for its working	Working models of objects	Engineering	Technology users	More males	Analytical activity	Australia, USA
Design-oriented	Individual creativity	Problem solving, making and design skills	Construction sets, tools, videos	Craft/Art	Problem solvers	Males and females	Creative production, problem-solving capabilities	Belgium, UK, New Zealand
Key competencies	Innovative designing	Design & analytical skills	Construction sets, machines, books, videos	Trained in industries	Creative workforce	Males and females	Innovative production	Japan, Australia
Science-Technology-Society (STS)	Understand science, technology, environment links	Critical thinking	Science classrooms	Science	Include negative effects of technology	Males and females	Social endeavour	France, New Zealand, USA

2.2.2 Technology in the Indian curricula

This section briefly discusses the structure of educational system in India and the features relevant to understanding its functioning. Further, an attempt is made to understand the place of technology in the Indian school system. In order to achieve this goal, school subjects which include manual and productive work were explored. Data about these subjects was gathered from primary sources such as policy documents, curricular frameworks, commission reports, field notes from the interactions with school teachers; and secondary sources such as literature on curricular and policy reviews. The intent of the discussion is to place the details in perspective about what is understood as "technology" in the Indian context. Knowing the education system in India will help discuss aspects of technology in the formal system.

The general structure of formal education in India

Since 1976, education is on the concurrent list, which implies that formulating policies and ensuring effective implementation of educational initiatives has been the collective responsibility of both the Central and the State Governments. The Ministry of Human Resource Development monitors the decisions related to education at all levels, from the primary to higher education. Throughout the country, depending on the bodies managing, schools are of following types: (a) Government schools (public sector undertaking and other schools which receive government-aid); (b) local-body schools (municipal corporations, municipal committees, notified area committees, zilla parishads, panchayat samitis, cantonment boards); (c) private aided schools (established and managed by private societies but receive maintenance grant from the government or local body [grant-in-aid schools]); and (d) private unaided schools (recognized by government but get no funds). The majority of schools follow the curriculum prescribed either by the Central or the State Boards. In addition to these schools, there are some schools managed by the Council for the Indian School Certificate Examinations (CISCE), 40 schools which follow the International Baccalaureate curricula, and a few open schools.

Following the recommendations of one of the most influential educational commissions, namely the Kothari Commission (1966), a common structure for education was adopted in several states in India (NCERT 1966). Typically, schooling is for a span of 12 years, popularly denoted as "10+2 pattern", which includes 10 years of primary and secondary schooling and 2 years of senior/higher secondary schooling (referred to in some states as junior college or intermediate). Graduation normally involves 3 years of study. A minimum of 200 instructional days per year is prescribed at the national level. The prescribed number of school hours for the primary level are 5 per day with a minimum of 4 hours of instruction. At the upper-primary and secondary stage, about 6 hours per day with a minimum of 5 hours of instruction is prescribed.

The National Council of Educational Research and Training (NCERT) is the apex body involved in formulating the curricular framework for the Central schools. The State Council of Educational Research and Training (SCERT), closely follows the guidelines recommended by the NCERT and formulates its own State curricula. All students are assessed through public examinations at the secondary (class 10, age 15 years) and higher secondary level (class 12, age 17 years) conducted by the respective boards, State, Central, ICSE, etc. Figure 2.1 gives a diagrammatic overview of the general structure of education in India.

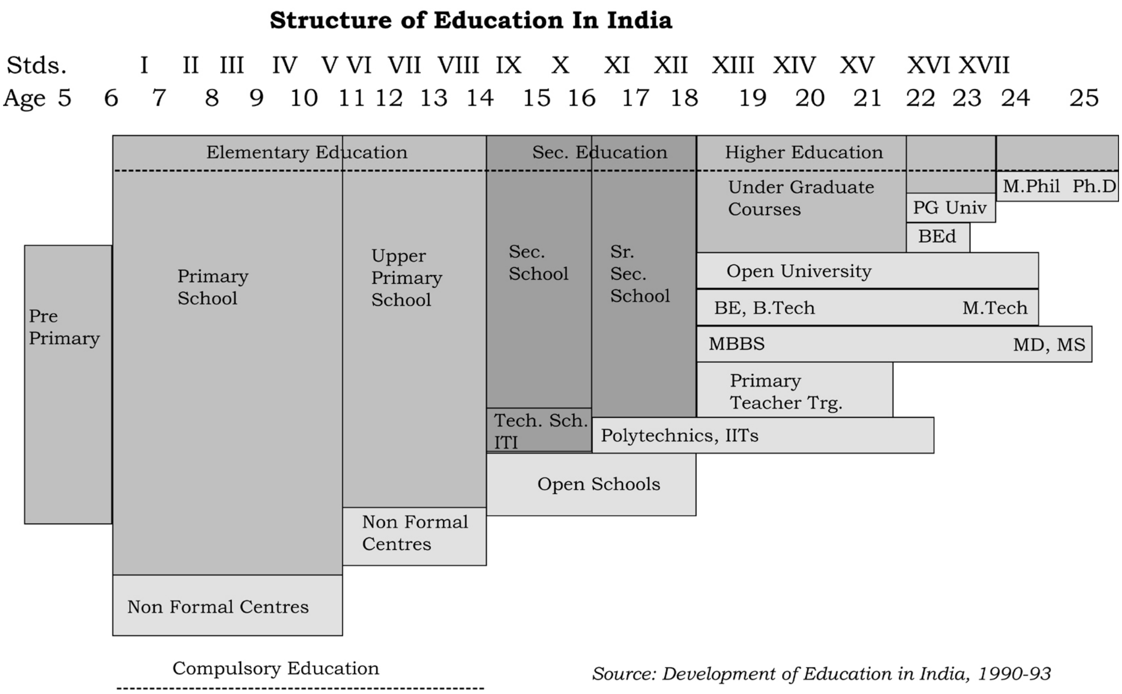


Fig. 2.1: Structure of education in India.

Technology as domain-specialisation

Technology education, as a discipline, exists only beyond the 10+2 stage, where graduate and post-graduate degrees are awarded. The only courses of technology offered at an earlier stage are limited to those in information technology. The specialised degree courses have over the last 50 years attracted the brightest students, because of the social perception and economic benefits in these professions. However, in the recent years, there are indications of change in terms of the number of students enrolling for these courses as well.

Technology as applied science

With an emphasis on science concepts, formulae and procedures for experimental activities, the school textbooks communicate at best the image of technology as applied science. The National Curriculum Framework for Science Education (NCERT 2000) had christened the school *Science* textbooks as *Science and Technology*, which through a curricular revision and by way of a new curricular framework (NCERT 2005) was rechristened as *Science*. The change of labels did not contribute in any sense to the element of technology in schools. By and large, and more so the classroom organisation provide very little scope for learning that involves creative manipulations and working with hands.

Technology as vocation

The first 10 years of schooling is largely an undifferentiated one. At +2 stage (class 10, age 15 years), a student can opt for an academic or a vocational stream. Formal and non-formal vocational education programmes upto higher secondary stage are co-ordinated by Pandit Sunderlal Sharma Central Institute of Vocational Education (PSSCIVE), a unit of the NCERT. Formal programmes are integrated with general education while non-formal programmes are meant for drop-outs (walk-outs), special groups (such as tribal population, women, handicapped and disabled groups) and the unorganised sector (such as agriculture, handicraft, social welfare centres, etc.).

Vocational education is included in the general curriculum either in the form of

Work Experience (WE) or Socially Useful Productive Work (SUPW). The disciplines had a broad aim to inculcate among learners a respect for manual work, values of self-reliance, co-operativeness, perseverance, helpfulness, work ethics, attitudes and values related to productive work and concern for the community. Work experience was proposed to be an integral part of general education at all stages of school education (NCERT 1975) while SUPW was prescribed for students in primary and upper primary stage (classes 1 to 7). These subjects provided some opportunities for learning how to *repair things* and know the working principles of objects in everyday use. These subjects tend to be neglected since they have not been included in the formal grading of student's academic performance.

At the lower secondary level (classes 8 to 10), pre-vocational courses are offered to prepare students to take up vocational courses at the higher secondary stage and also to address the problem of massive drop-out of students at this stage. Pre-vocation courses impart training in simple marketable skills, preparing students to enter the world of work and allowing for self-exploration of vocational interests. Only a few schools offer pre-vocation courses, which are usually electives. If at all popular, they are because of the information technology content that orients students to the use of computers.

Vocational education at the higher secondary or the +2 stage aim to develop competencies (knowledge, skills and attitude) required by a specific occupation, through diversified vocational courses, especially for self-employment. Apart from these, some generic vocational courses (GVC) provide employment related generic skills needed by an educated work force, regardless of the person's occupation. Vocational schools, affiliated institutes, junior technical schools enroll students for diplomas and prepares them for the organised sector. After the vocational course, a student can opt for an "apprenticeship training course" that trains a person in the specific skills required by the industry.

Vocational subjects are greatly undervalued by the society at large. If present in the school time-table, these courses are electives which are often taken over for completing the syllabus in science and mathematics. The aesthetic, manipulative and organisational aspects of technology also do not receive sufficient attention and have a status similar to WE.

Technology as technical education

Courses that cater to the special requirements of the industries are conducted by the Industrial Training Institutes (ITIs), which come under the control of the Ministry of Labour. The enrolling candidates are those who have passed the class 10 public certificate examination. There are a few courses designed for post class 8 students. The polytechnics provide a three year diploma course for 10+ students.

Specialised technical institutes are co-ordinated by the All India Council of Technical Education (AICTE), the national apex body on matters of technical education. Technical education is offered at several levels, such as craftsmanship certificate, diploma, degree, post-graduate and research in specialized fields. In general, vocational and technical education courses at the school level are perceived as courses meant and opted for by students considered “academically weak” (Anand 2003).

Summary: Place of technology in the Indian curricula

The Indian school curricula which does not have technology education as a component in the formal schooling presents a case very different from several other countries in the world, where technology education has been introduced in the last few decades. Exposure to the working aspects of technology largely comes from elementary school subjects such as WE/SUPW and Art education. Subjects like science, social studies and languages merely have some text about technology in the textbooks. The secondary years of school have a few courses including manual work in the form of elective pre-vocational courses. These courses address the needs of skilled human resources for the shop floor of local industries, not professional technologists. Such vocational courses usually have few takers. The disproportionate distribution of students in the academic and the vocational stream reflects the state of a society in which technical, artistic and work skills are not given their due credit, a concern which is being raised in the recent school curriculum reforms (Sadgopal 2005). Courses structured to train technologists and engineers start only after 12 years of formal schooling. Thus, the overall system of exposure to manual work is biased to the academic streams. The duality between the mental and the manual, is thus both systemic (structured) and a result of our social perception, each influencing the other.

In all these interpretations from work experience to vocation, technical to domain-specialisations, some elements of technology activity get obscured. The possible approaches for teaching technology and the means used convey a narrow and limited perception of technology. Qualitative explorations and informal interactions with teachers and students reveal that in the Indian context, vocational and art education subjects do not receive sufficient attention. On the contrary, opportunities for engaging students in creative and productive endeavours are usually taken over for teaching subjects considered academically important such as science and mathematics. The cultural divide between the manual and mental is already deep and deepens further with continuing practices.

2.3 Studying ideas about technology

Having looked at curricular approaches and the concerns and priorities that influence its implementation, it is also necessary to understand from the viewpoint of students as to what they perceive as technology. For example, do they hold a view which is the reflection of what they learn? What role of technology do students perceive for them as individuals and for the society? What all contexts do they associate as being influenced by technology? Do these perceptions differ in different spheres of human activities? Answers to some of these questions can be sought in literature on attitudinal studies and those on perceptions about technology. Before venturing into the attitudinal studies, let us briefly understand what an attitude implies and its relevance for our research.

2.3.1 Attitudinal studies: meaning and scope

Historically, the meaning of the term *attitude* has evolved. Science educators agree with the definition proposed by Fishbein and Ajzen (1975) who described *attitude* as "a learned disposition to respond in a consistently favourable or unfavourable manner toward an attitude object" (Shrigley, Koballa Jr. and Simpson 1988). The attitude object may be a specific object, institution, a person, an issue, event or an idea. Attitudes are enduring dispositions which are unlikely to change under ordinary conditions. Hence, attitudes serve in many ways to predict or influence future actions.

Attitudes are learned, either actively or vicariously (Shrigley 1983). Students develop likes and dislikes and suitable models can induce socially desirable attitudes. Once attitudes are established through experiences, they enable or inhibit further learning opportunities (Coon 1995 cited in (Volk 2007)).

Attitudes are related to behavior; that is, people's action reflect their feelings toward relevant object and issues in a probabilistic way (Koballa 1988). Attitudes toward technology influence students' decisions and actions. The experience students have with objects, activities and individuals associated with technology impacts their attitudes in areas such as interests, career aspirations and role patterns identified with technology. Familiarity with the attitude object, on the part of the person concerned, is a necessary precondition for assessing his/her attitude to the object. This involves acquaintance with the nature of the object, and necessitates its relation to other relevant objects within the knowledge of the person (Schibeci 1983). Attitudes involve to differing extent a *cognitive* component, consisting of a person's beliefs about the object; an *affective* component, consisting of a person's feeling about the object; and a *conative* component, consisting of a person's intentions to act in a particular way toward the object. It is difficult to see these components in isolation as these vary in degrees in a given attitudinal study. Nevertheless, it is one means of ensuring a balance of items within an attitudinal scale.

Attitudes are influenced by the socio-cultural influences (Shrigley et al. 1988). Hence, Shrigley (1983) suggests that attitudinal scales (instruments) should reflect the personal nature of attitude with egocentric items, the social influence subconcept with social-centered items, and the consistency subconcept with action-centered items. Attitudes are evaluative and the consistency of responses to an object or situation is indicative of a relation between attitude and behaviour.

In the context of technology education, knowing students' ideas about technology may help tailor learning engagements suitably. In the Indian context, which does not have technology education as a school subject, an attitudinal study will give an insight into what students in general think of technology and what they do/do not associate with technology. At the level of research, probe studies can be planned which are usually done at a micro-scale involving a focussed target group or a macro-scale covering a wide spectrum of sample to gain insights into the general trends. Given the purpose of understanding what students in general think about technology, a macro-scale investigation perhaps would be productive. Research in education uses attitudinal studies as a strategy to understand the linkage between curricula and students' ideas.

2.3.2 Insights from studies across the globe

Understanding ideas about technology has been of interest to research groups studying ideas about science, scientists, about the nature of relation between science and technology, and those probing the notion of Science-Technology-Society (STS). It is through systematic efforts in such contexts that the notion of technology has been pursued in empirical investigations. Though these studies were designed for a different purpose, they nevertheless give some idea of what students and adults perceive of as *technology*. With the introduction of technology education in some countries, investigations in the last few decades were specifically aimed at probing students' ideas about technology. This section gives an overview of some of the large-scale investigations across the globe. The cross-cultural studies give an idea of perceptions from a wide range of contexts or at times make comparisons across several contexts. This is followed by investigations in local contexts, which cover the breadth of studies and issues that revolve around technology.

A transnational study on students' ideas of *Science and Scientists (SAS)* by Sjϕberg and collaborators, involved 21 countries, including India (Chunawala and Ladage 1998) and participation of more than 40 researchers. The study was conducted with a sample of about 10,000 pupils, aged 13 years, representing all continents. The study was an endeavour to explore cultural and gender differences on issues that are of relevance for science and technology (S&T) teaching and learning. The study reported that students in developing countries perceive learning about S&T a privilege and in general exhibit much higher interest than those in the rich and technologically developed countries. The same phenomena extends to girls who in much more proportion than boys, have a very positive opinion of S&T. Gender differences were observed to be greater in the rich countries (Sjϕberg 2002). From the viewpoint of S&T relationship, the study emphasizes that the perceptions and needs of cultural contexts, boys and girls are different. Curricular experiences need to be tailored to attract student engagement in science and technology.

Technology as seen in STS studies aimed to understand what students perceive of the three concepts, namely science, technology, society and the inter-relations between them. Aikenhead and his colleagues (1987), developed and administered a questionnaire called *Views on Science-Technology-Society (VOSTS)*. The study conducted with Canadian high-school graduates (grade 12, age range 14 to 27) has been extended to several other cultural contexts. The study revealed that students perceived S&T as a unified enterprise, namely *technoscience*, and failed to appreciate the role of each. Students' responses indicated a preference for a technocratic model, a belief that scientists and engineers can resolve socio-scientific issues and can make important decisions about social issues (Fleming 1987).

Another important cross-cultural study has been the ongoing *Relevance of Science Education (ROSE)* project, an international comparative research project involving 150 researchers and more than 60 countries, of which India is also a part. The project initiated by Sjϕberg probes students' (age 15 years) perceptions of the importance of S&T learning (Schreiner and Sjϕberg 2004).

The 1980s evidenced debates on the need for introduction of technology education in general school education. Many studies were undertaken to study students' and teachers' attitudes towards technology. The transnational project on *Pupils' Attitudes Towards Technology (PATT)*, initiated by Raat and de Vries in early 1985-86 at the Eindhoven University of Technology, aimed at understanding students' attitudes and concepts of technology (Raat and de Vries 1986). This instrument was modified and adapted to suit the context of United States in 1988 and was referred to as PATT-USA, designed for middle/junior high school students in the age range 11-14 years (de Vries, Bame and Dugger Jr. 1988).

PATT surveys conducted in several countries across the world have given insights into students' attitudes towards technology in different educational and socio-cultural contexts. Some common findings across contexts reveal that pupils' in general have a positive attitude towards technology. Students and pupils more readily recognized technology as objects than as other manifestations of technology (knowledge, process and volition). In general, products like computers and electronic devices were predominantly related to technology. Significant differences were noted between girls' and boys' perceptions of and attitude toward technology, and it was found that more often boys expressed their interest in technology than did the girls (Corread 2001, Barak 2000, Heywood 1998, Bame, Dugger Jr., de Vries and McBee 1993, de Klerk Wolters

1989). What are the perceptions of Indian students? Do they think of technology in much the same way as their counterparts across the globe? A review of studies carried out in the Indian context helped us in knowing the Indian perspective.

2.3.3 Attitudinal studies in the Indian context

A PATT study was carried out in India in 1980s with an aim to probe differences in attitudes of girls and boys towards technology coming from rural and urban settings. A sample of 1167 respondents in class 12 (age group 16+) were drawn from a major industrial city and 10 small villages in Madhya Pradesh state in India. Boys seemed more confident about their technological competence as compared to girls. However, on most scales differences between girls and boys was not significant, except on the concept scale. Researchers concluded that the differences seen in concept, self-estimation of technological competency and technological prospects, came from the differences in urban and rural settings (Rajput, Pant and Subramaniam 1987, Rajput, Pant and Subramaniam 1990).

A recent study by the National Council for Science and Technology Communication (NCSTC) probed higher secondary students' ideas on a wide variety of areas of science, technology and social studies. The issues of concern were freedom, democracy and rights and duties of citizens. Aspects of technology formed a negligible part of the broad study carried out among 50,000 students of class 11 (aged 16 - 17 years) from several schools located in 300 districts of 18 States (Raj 2002). Findings based on items related to technology indicated that students in general have a very positive opinion of technology for the society, concurring with the finding of the ROSE studies. The scale of the study though massive had a narrow focus for concerns on technology.

A questionnaire survey was recently conducted by the National Council of Educational Research and Teaching (NCERT) with 115 students from classes 7 to 12 (age 12 to 18 years), from different Indian States who participated in the National Science Exhibition for Children. The analysis of their open-ended responses to questions revealed 3 distinct features of technology as: (a) application of science (25%); (b) a branch of science, a science of techniques with new ideas (55%); and (c) that which solves problems and improves the quality of human life, society and the environment (32%) (Bhattacharyya 2004).

2.3.4 Technology education in India: A summary

Studies probing Indian students' ideas, attitudes or perceptions of technology have been few in number. Not all the instruments used were designed to study students' ideas about technology, and targeted mostly students in higher secondary schools. Over the years, due to rapid influx of technologies, the "world of artefacts" has undergone a considerable change in a short span of time and may have had an impact on people's life styles and attitudes. Besides, India represents a unique context characterised by a rich tradition of diverse local communities making their living from a variety of technological engagements. On one hand, it has communities that thrive on handicrafts based industry such as weaving, pottery, bangle-making, etc. and on the other hand, a mental – manual divide pervades the society. Given the diversity of contexts and differential levels of technological engagements, what ideas, activities, and consequences do students associate with technology? This and other aspects that contribute to our understanding of students' perceptions of and attitudes towards technology need to be studied. An appropriate instrument that integrates questions on local contexts can be used to probe such ideas. Further, insights from such an understanding would help integrate activities that can challenge or tailor learning situations that encourage students to be critically involved in technological engagements.

2.4 Initiating interventions for technology education

Given the fact that technology influences us in different and significant ways, the absence of technology in our formal schooling is a matter of concern. A meaningful integration of technology in our school education requires technology education to go much beyond an exposure to manual work and needs to integrate crucial aspects such as allowing negotiation of design problem, including aspects of designing, judging the strengths and weaknesses of an anticipated solution, and working together in teams. What conditions need to be provided in order to have a fertile environment that encourage such an interaction? What aspects need to be included to make the trials receptive, engaging and a worthy learning experience? Answers to these questions lie partly in the theoretical understanding that guide the design of the units and partly the empirical studies on students' ideas about technology. The suitability of the units can best be judged based on the trials. What theoretical underpinnings can guide a research in this field? Insights from educational philosophy and theories of learning may suggest the factors that inform and suitably tailor learning.

2.4.1 Theoretical convergence

The idea of what constitutes an enriched learning experience has been argued and debated over several decades. Prominent among the efforts are those of social reformers and educational philosophers. This section draws upon the points of convergence with respect to some of the ideas and views related to technology education.

Influential ideas of social reformers

Social reformers who saw education as a means to bring about social change have voiced their opinion on how it should be structured so as to achieve greater benefits. Mohandas Karamchand Gandhi, popularly known as Mahatma Gandhi or Father of the Nation, was one of the most influential leaders who led the Indian independence movement. He visualised "Basic (*Buniyadi*) or New education (*Nayee Talim*)" as an important component of the constructive programme, a truthful and non-violent means of winning *Poorna Swaraj* or complete freedom (Gandhi 1945). Gandhiji denounced the then existing system of education enforced by the British and emphasized an alternative model for schooling which would develop both the body and the mind. He wrote, "Craft, Art, Health and education should all be integrated into one scheme. Nayee Talim is a beautiful blend of all the four and covers the whole education...Instead of regarding craft and industry as different from education, I will regard the former as the medium for the latter" (Gandhi 1968). He argued for an education that would create a productive base in the Indian villages by reviving village industries, crafts and other productive activities of village life. Gandhiji's ideas have been tried in a few alternative schools. However, at the national level it did not gain much success.

Rabindranath Tagore, a poet, writer, painter, connoisseur of arts, philosopher, and the first Asian Nobel laureate, was a contemporary of Gandhi. He envisioned education to be deeply rooted in one's immediate surroundings but connected to the diverse cultures of the world. He believed that education is for personal-fulfilment and self-improvement. He started a school in 1920s called the "Shikshasastra" at Sri Niketan, which enabled a decent livelihood for students alongwith their engagement in learning. The school schedule covered several activities in agriculture, education, health and social life in the villages. Handicrafts was a compulsory trade for all students.

Margaret Noble or Sister Nivedita was an Anglo-Irish social worker and a disciple of Swami Vivekananda, who worked for the upliftment of women and also started a school for girls. She emphasized the role of manual training in general education and especially in village education.

All these efforts aimed at the holistic development of an individual and in their own ways tried to bridge the gap between the manual and the mental. Similar ideas have also been in the arguments of educational philosophers in other parts of the globe.

Insights from educational philosophers

Educational philosophers have also tried to revitalize education. Significant from the point of technology education has been the work of Lev Vygotsky and John Dewey. Vygotsky's sociocultural approach empahsizes the fundamental role of social interaction in the development of cognition. Vygotsky (1978) states that "Every function in the child's cultural development appears twice: first, on the social level, and later, on the individual level; first, between people (interpsychological) and then inside the child (intrapsychological)." Vygotsky's signified the role of mediated activity, which was extended by his colleagues A. N. Leont'ev and A. R. Luria. The idea led to conceptualisation of the Cultural-Historical Activity Theory (CHAT). According to this theory, an individual does not merely react to the environment as in the case of reflexes in infants. Human actions have a tripartite structure of subject, object and the mediating artefact. The relationship between human agent and objects of environment is mediated by cultural means, tools and signs (Engeström 2007). Cognitive change involves internalisations and transformations of the social relations in which children are involved, including the cultural tools which mediate the interactions among people and between people and the physical world (Newman, Griffin and Cole 1989).

John Dewey has emphasized the need for training individuals in thinking and the centrality of reflection and uncertainty in thought. Reflective thinking, according to him, involves willingness to endure a condition of mental unrest. In fact, maintaining the state of doubt and carrying on systematic and protracted inquiry are the essentials of thinking (Dewey 1991). This is a valuable insight, especially in the case of design activities, which involve a lot of uncertainties while solving problems. A theoretical position which takes into account the role of investigation and uncertainties during exploration of design ideas then comes to be valued in school learning.

Insights from contexts of learning

The discussion on technology and the several approaches to technology education had central to it the aspect of change in the human environment to meet human needs and desires. This change is not random but a thoughtful and a preconceived one. In other words, it involves the aspect of design emphasized to differing degrees in the diverse approaches. The design approach, practised in UK lay a very strong emphasis on design and sees it as a process central to human thinking and problem-solving.

Design does not take place in isolation. It involves people who interact and share their ideas in order to realise a solution. Besides, it is known from the situated learning theories that context plays an important role in the acquisition of representations of knowledge, procedures and competencies. This aspect of technology problem needs to be integrated in technology education. Through this integration, the traditional dualities of mental and the manual, the concept and practice can be challenged. Technology education with a practice that features learning involves creating and sharing meaning. Rather than seeing learning as a process of transfer of knowledge from the knowledgeable (teacher) to the less knowledgeable (learner), a situated view is concerned with engagement in culturally authentic activity. Recent studies have unearthed that the social differences that exist among different cultures affect the nature of their cognitive processes (Nisbett 2004). It is therefore necessary to understand and practice technological problem-solving taking into account the context. The convergence of our theoretical understanding coupled with the knowledge of diverse approaches and the varied emphasis of the aspect of design that leads us to discuss a few aspects of design in the next section.

2.5 Understanding design

The term "design" is derived from its Latin root *designare*, meaning to mark out, trace, denote, or devise. It has cognates in Italian language like *designo* meaning drawing and in French such as *dessein* meaning plan or purpose, *dessin* meaning drawing or sketch. However, there is no word in classical Hebrew or Greek suggesting that the origins and usage of the word is modern (Mitcham and Holbrook 2005). The English word *design* can function as either a verb or a noun. As a verb, it means to mark out, nominate, appoint; to plan, propose, intend; and to draw and sketch. As a noun, it represents a mental plan and artistic shape.

The term *design* takes multiple meanings in its context of use (Bucciarelli 1988). As a noun, it may refer to an artefact that draws admiration such as clothes or a car. As an act of planning and conceiving it can be applied to a diverse range of human experiences. From the artists and architects who see design fundamentally as a creative activity to engineers who design structures, devices, processes, and systems; from musicians who design compositions; poets and novelists who design their works in literature to scientists who design hypotheses and means to test them; teachers who design their curricula and classroom interactions, humans in diverse arenas have been designing. Design involves anticipation or thinking in advance about how to go about doing something. In essence, design turns making into thinking - a thinking beforehand about how to make. Design thinking is often mediated through drawings and gestures.

2.5.1 Drawings, design and cognition

Often the domains of drawings, design and cognition – all domains of human activity are perceived as independent. There have been little efforts in the past towards establishing a common ground. Focus on issues at the interface of these three domains provide valuable insights into their role in technology education.

Drawings and their multiple functions

From ancient era to present age, drawings have been widely used as a tool for expressing human thoughts, ideas and emotions. In fact, it has been reported that in the historic development of languages, visuals had much preceded the written language (Tversky 2005). Not just the historic development, drawings are an important aspect of cognitive development of an individual. Developmental psychologists believe that a child's progression in spontaneous drawings, mirrors the cognitive growth of a child (Piaget and Inhelder 1995) and have used them as tools for studying the developmental sequence in the early stages of learning (Gardner 1980). Drawings serve as a means of expression, exploration and discovery. As an effective tool for diagnosis, drawings have been employed to probe and assess students' ideas in a number of domains: plants and forests (Natarajan, Chunawala, Apte and Ramadas 1996), human body systems (Mathai and Ramadas 2006), motion (Ramadas 1990), science and scientists (Chambers 1983) and technology (Rennie and Jarvis 1995a). It is a multipurpose tool for enquiry, comprehension and communication (Adams 2002); for organising and representing ideas; for analogical (Casakin 2004), and visuo-spatial (Tversky 2002) reasoning; and a recording medium (Hope 2000). Drawing as a socio-cultural activity is reflected in symbolic and cultural conventions or resource preferences in productions (Anning 1997). Drawings may sometimes be regarded as externalizations of images, but contrary to this view, drawings reflect conceptualizations, not perceptions of reality and hence differ from images (Tversky 1999).

Design using drawings

Drawings, which play an important role in design, are at the heart of technological activities. Real-world design problems are "wicked" or "ill-defined", not neatly formulated, have multiple clients and decision makers with conflicting values (Rittel and Webber 1984). In such situations, the paper-pencil mode is a useful medium to externalise and operate on ideas. Practitioners of technology, 'read' drawings because they understand and share symbol conventions (Do and Gross 1996). Arguing for cognitive modelling as the essential language of design, Roberts (1994, p174) asserts that the language enables an individual "to form images in the mind's eye, of things and systems as they are, or as they might be, and evaluate them and transform them so as to gain insights into their structure and into their likely quality to fit between alternative conceivable configurations and the interaction of perceivable interactions."

The image usually gets externalised and communicated through models and simulations, such as drawing, diagrams, mock-ups, prototypes and where appropriate, language and notation. Many designers and engineers acknowledge the richness of design drawings as the non-verbal or the visual language of technology (Cross 1982).

In the classroom contexts as well, design drawings can be an effective tool for representing ideas or objects, as a tool for learning and recording thinking in classrooms (Anning 1997). Design drawing is an external representation that helps in problem-solving and generating ideas (Ullman, Wood and Craig 1990). Designing with drawings serves the dual function of showing designers how their ideas look and if complete, show workers all the information needed to produce the object (Ferguson 1994). Design drawings as against other drawings convey several characteristics of topology, shape, size, position and direction (Do and Gross 2001).

Cognition in design

Design is a fundamental human capacity to plan and model ideas with an intent to address the real-life problems which are largely ill-defined (Roberts 1994). Design drawings help mediate and externalise thoughts and ideas, even among very young children (Hope 2003). They serve as a convenient tool for visualising and mediating problem-solving for people of all ages (Edwards 1987). Young students use drawings with ease to suggest novel and innovative ways for solving complex social problems (de Bono 1972). Design thinking, concerned with structure as well as function, uses mental imagery, modelling, pattern-formation, and synthesis. Designers, architects and engineers are known to think visually using design drawings to ideate and think of objects and their assemblies. Engaging in design activities builds values of practicality, ingenuity, empathy, and a concern for appropriateness (Cross 2002). Aspects of design and cognition are discussed at length in Section 2.8.

2.6 Synthesizing Design and Technology

Design and Technology are not isolated entities but operate in synergy. Arguments for the role of design in technology come from the justifications for design as a culture, and its role in technological activity and learning. Design as a third culture is distinct from the sciences and the humanities, but integral to technology. Central to this argument, is the finding that, there are ‘designerly ways of knowing’ and thinking, which are distinct from those in the other two cultures (Cross 1982).

The second argument relates design to be an integral part of the technological activities. Solomon (2000) considers *designing* as an activity that distinguishes ‘technology’ from the older craft lessons. She believes that without designing, the technological activity could turn into a messy, unplanned affair, full of trials and errors. Another variant of the second argument, but stronger in its implication, is the visualisation of the “design process” as the unifying element between the different material areas of Design and Technology education (Eggleston 2001) and the process of technology operates under the influence of resources and restraints as shown in Figure 2.2.

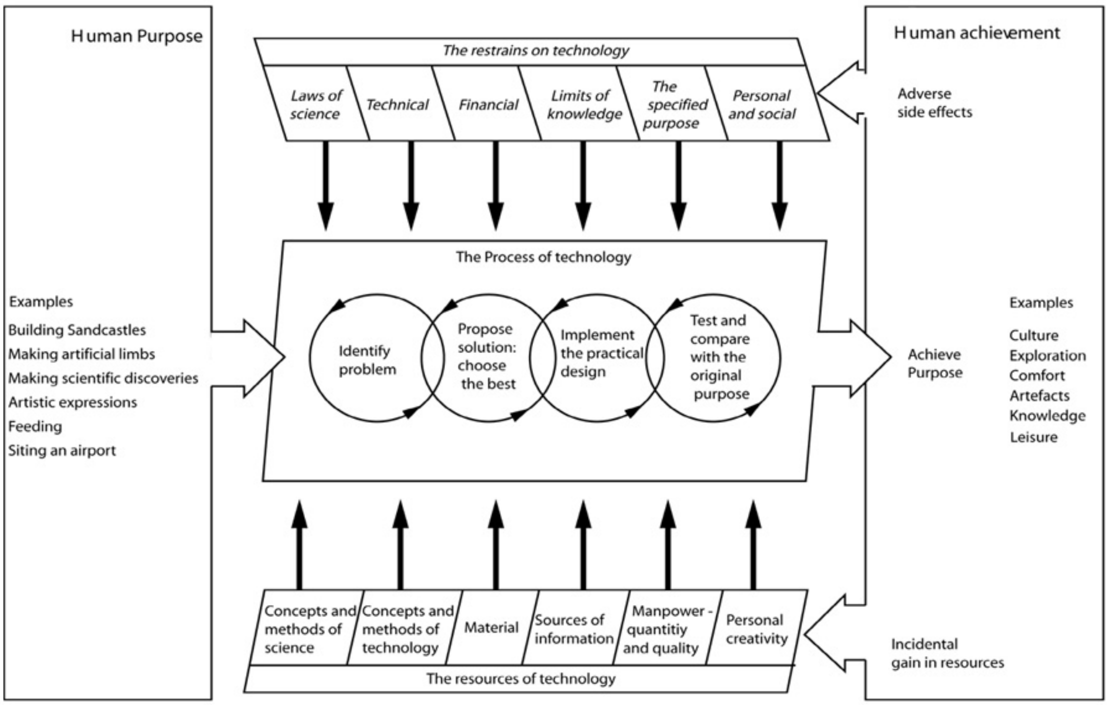


Fig. 2.2: The process of technology (Eggleston 2001).

One of the strengths of design is its role in linking thought (mind) and action (hand), the two cognitive processes which are separated in contexts of formal learning. The imposed duality between the mental and the manual runs deep in our culture and has been discussed in Section 2.3.4. In contrast to this understanding, design thinking progresses through an iterative interaction between mind and head. This interaction is depicted in the APU model reproduced as Figure 2.3.

The model shows that design begins with hazy conceptions, uncertainties and through

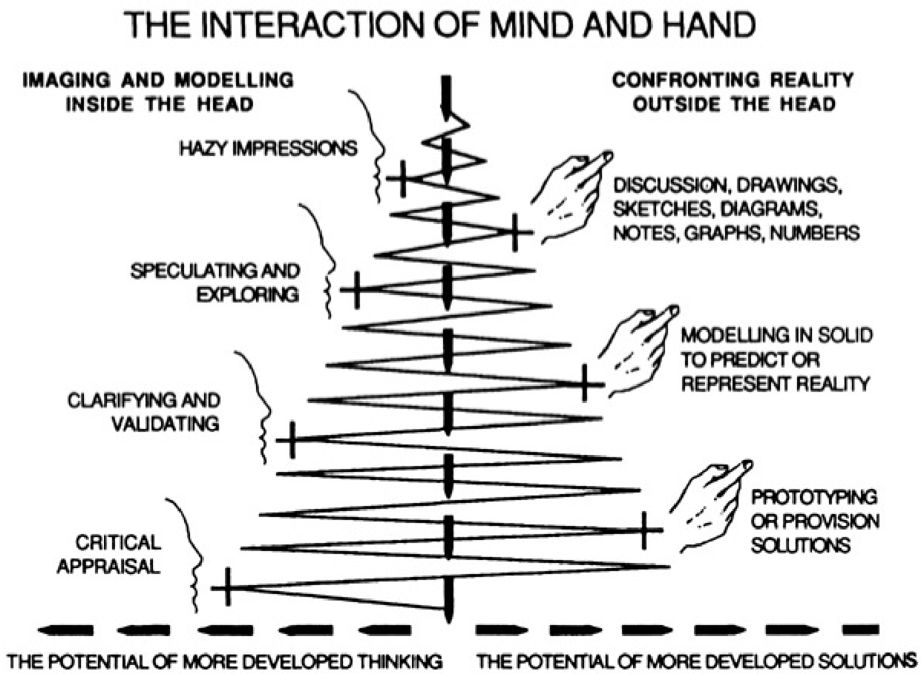


Fig. 2.3: The APU model of interaction between the mind and the hand (Kimbell et al. 1996).

transformative processes comes to a working reality. These processes cannot be prescribed in advance, they need to be engaged in responsively, led by the demands of the task and the idea itself (Kimbell and Stables 2007).

2.6.1 Design, making and cognition

Design gets actualised when it receives a material form. The process of translating conceptualisations into real-world artefacts or systems engages students in practical learning. Practical learning is a purposeful activity with making as an essential core, and is located in pupils' experiences and contexts requiring students to make sense of the experiences. In making judgements about appropriate material resources and tools, students engage in the process of meaning making. Senesi (2000) studied French pre-primary school children (aged 3-6 years) and analysed their drawings and utterances about artefacts like scissors, before and after allowing them to handle and make the artefacts. The studies revealed that after the construction activity, there was significant progress in students' concepts and knowledge of the origin of artefacts and of tool use.

Design without drawings is at times possible and is recognised as the artisan's way of designing (Ferguson 1994). But, designing using drawings has many advantages, some of which we have noted in the earlier section. Besides other advantages, design drawings are a means of saving physical effort and material resources with mental effort (Mitcham 1994).

2.7 Aspects influencing design and technology education

According to de Vries (2002), research in technology education relates to three fields: the aim and content of curricula (*what to teach*); the characteristics of pupils, like the preconceptions and attitudes (*whom to teach*); the creation of adequate educational situations in which the right content is conveyed to the learner (*how to teach*) and includes assessment strategies and tools. The aspects that cover these three fields are discussed below under the heads of motivational concerns; knowledge, skills and values; pedagogical models; classroom interactions, classroom resources, socio-cultural aspects of learning, evaluation and assessment practices.

2.7.1 Motivational concerns

Throughout history, humans have modified their environment and tailored their lives to satisfy their needs and desires. They have done this by imagining new possibilities, putting their ideas into action and evaluating the outcomes to decide whether their need has been met. In this sense, the process which is the essence of design and technology in schools is one which has had a fundamental part to play in the development of human society (Ritchie 2001).

2.7.2 Knowledge (concepts), skills and values

The content of technology education includes the concepts (knowledge), skills and values afforded by a D&T unit. From a technological domain viewpoint, Rophol (1997) has identified 5 knowledge types in technological practice: (1) Technological laws (of theories, concepts), (2) Functional rules (recipes for doing), (3) Structural rules (of assembly which come through experience), (4) Technical know-how (skills of sensory-motor co-ordination, which comes through practice), and (5) Socio-technological understanding (includes reflection on pre-conditions and consequences of work).

In referring to design learning among professional designers, Eastman (2001) emphasizes that knowledge may be seen in terms of four categories, namely; factual, informal, procedural and experiential. He proposes that there is a process of manipulation, of 'generate-and-test', in which a designer's pre-existing knowledge is brought to bear on a design task, which in turn is the spur to seeking new knowledge and hence new learning.

From an educational viewpoint, technology educators have variously classified the knowledge and skills gained in a D&T education unit. Robert McCormick (1997) identifies two kinds of knowledges, viz; the conceptual and the procedural knowledge. Conceptual includes factual knowledge about concepts and their relations whereas procedural includes technical skills of doing, strategic thinking, rules of thumb, etc. The first three kinds of knowledges as described by Rophol fall into the conceptual category.

From the point of assessing students, 3 levels of knowledge can be applied in a task, which are illustrated using an example from Kimbell (2007):

Black box: I do not know how it (e.g. a torch) works, but I know it does.

Street level: common knowledge on the street (I know the torch has batteries, a bulb and a switch and that they are somehow connected).

Working knowledge: I know enough to manipulate/modify the product (I can rewire the torch to make it behave differently).

The ability to represent and develop thought through visual forms is often overlooked. Graphical talent in young children appears to be more spontaneous than writing or number (Cross 1986). Skills in graphicacy and abilities to visualise and represent an artefact or a system involves making quantitative estimates and reasoning. Schools emphasize literacy, numeracy and verbal modes of thought and expression. However, students often resort to the non-verbal modes of communication in design problem-solving situations. Through D&T units we need to integrate and value these knowledges and skills.

2.7.3 Pedagogical models

An attempt has been made to present an overview of some of the pedagogical models used for teaching technology in different contexts. This will help explore the spectrum of practices and highlight the useful features in different approaches. The labels used help distinguish between the different models.

Skillful reproduction

Classroom teaching that follow a set of prescribed activities become a classroom ritual for reproducing products following a procedure-based scheme of actions. Technology education is visualised as a vehicle to teach skills and procedures through “making” engagements. Often curricula which follow an industrial arts, manual training, craft or a vocational approach end-up following such a pedagogical model of learning. In such an approach, the intention is to replicate a prototype and constraints are limited to just the techniques and the materials available. The activity is limited to the studio or workshop environments. The asymmetry between the “knower” and the “learner” is strong with the teacher as an expert passing on the knowledge and skills to the learner.

Project-based inquiry

In this approach, the goal is well-defined one and some critical constraints are stated, which are often tailored to yield to an objective method of assessment. However, there exists a flexibility in terms of the use of materials, resources, etc. The problem statement is given to participant/s well in advance and a period of time is allotted so that the individuals or groups can try and work out solutions. There is scope for generation and evolution of an idea. An efficient product ultimately becomes the unit of assessment. This model according to Barlex (1994), involves the following categories of learning: personal qualities, attitudes and values, understanding, knowledge and skill, which can broadly be classified as issues of awareness, capability, and resources. The educational outcomes are depicted in Figure 2.4.

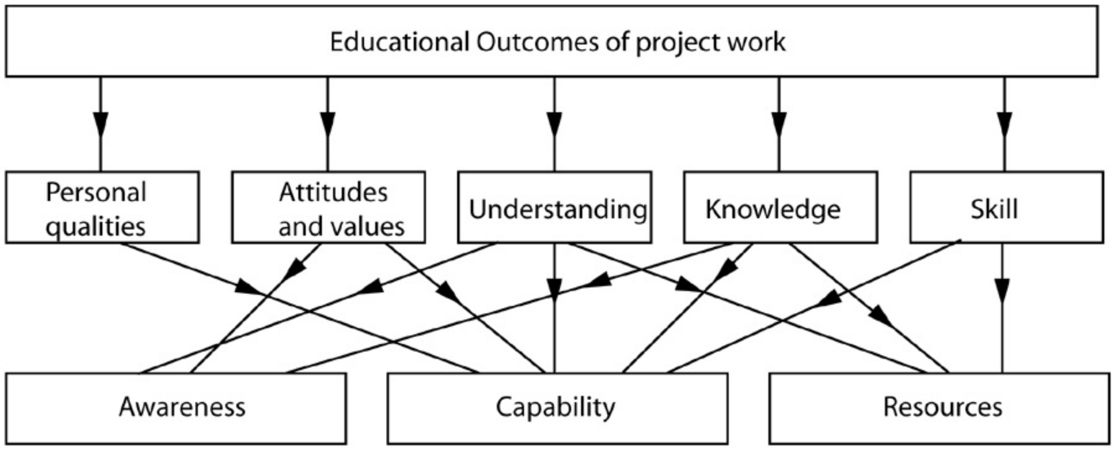


Fig. 2.4: Educational outcomes of project work (Barlex 1994).

The model also has certain limitations like matching pupils' ability to project difficulty, procuring material resources because of financial constraints, access to expertise, and the class size. Besides, project work may also be aimed for qualifying and earning a reward in competitions. Learning gets limited to the "doing or completing". Reflective accounts and richness of the evolution through the process of activity remains unnoticed, unshared and therefore, not harnessed. Examples of these include the project competitions in Engineering sciences, Robotics, etc. Science projects, which are a part of the "out-of-school activities (OSA)" are also a variant of this. Students strive to produce a novel workable product that fits into the theme for the competition and the primary motivation is reward. In such contexts, innovations quite often are a mix of accidents, purposive investigations (Bhattacharyya 2004).

Problem-solving

Sanders (2001) while reviewing the status of technology education practice in the US, observed that one of the valued purposes perceived of technology education is the ability to solve problems. At the same time, he cautions us of the multiple ways in which "problem solving" may be interpreted. According to him, in the context of technology education, problem solving approach is perceived as one in which students design and build solutions to problems posed by the teacher.

Hennessy and McCormick (1997) bring out the distinction between *problem-based learning* and *problem-solving methods*. The former refers to situations wherein problems are given to solve and the purpose is to help pupils understand certain concepts or ideas in the subject where the *process* of solving the problem may be unimportant. Problem-solving methods, on the other hand, refer to the processes involved in solving, such as recognising a problem, generating and implementing a solution, evaluating a solution, etc. and the understanding of concepts is of secondary importance. According to Hennessy and McCormick, D&T education as practised in the UK uses a problem-solving approach. This is done through the 'design and make' activities.

Cognitive acceleration

The notion of cognitive acceleration was developed in the mid 1980s by Michael Shayer and Philip Adey at the Kings College London. Central to this model is the idea that student's thinking should progress from concrete to the formal and abstract. Lessons designed to achieve this include 5 processes: stimulus to thinking and introduction which sets the scene (concrete preparation), a puzzle or challenge which needs to be solved (cognitive conflict), group-work where pupils share ideas for solutions, dialogue with others that extend thinking (social construction), sharing answers with the whole group, explaining the thinking and how one arrived at the solutions (metacognition), and making links to everyday applications, reviewing where else can the thinking be applied (bridging). Cognitive acceleration was developed for science teaching and has been adopted for teaching mathematics and technology.

Cognitive Acceleration through Technology Education (CATE) involve activities that are purely cognitive in structure, that is, there are no 'hands on' practical or making activities. The focus is on classroom discussions which mediate development of student's thinking, reasoning and problem solving capability. An exchange of ideas and strategies, justifications for choosing a strategy form the core of discussions among students and teachers. The idea is to challenge individuals to think and appreciate the multiple views and encourage individuals to communicate in a social group the rationale for making a decision. For example, students discuss in a class an effective means for disassembling an existing tiled mural and reinstalling it in another place (Backwell and Hamaker 2004). Thus, in this approach, problem-solving happens through explicating and justifying alternate solutions and leads to choosing the most effective solution. The teacher acts as a facilitator who raises doubts, challenges ideas and creates situations for students to make their ideas explicit. Communication is at the heart of such a pedagogical model.

Cognitive apprenticeship

The notion of cognitive apprenticeship has evolved over the last two decades to become more encompassing. Derived from the notion of an "apprentice" often noticed in real-life situations, the cognitive apprenticeship (CA) model involves learning environments which involve an interaction between a teacher (an expert) and a learner (a novice). As in traditional apprenticeship, learning happens by observing the master executing the process, followed by the apprentice carrying out the process under guidance of an expert, what is referred to as guided participation. As the learner masters the skills, the role of expert fades until the learner acquires the capability to accomplish the tasks entirely on her/his own. Unlike traditional apprenticeship, CA employs a sequence of tasks that takes into account the changing demands of learning. Besides, it aims for generalising knowledge so that it can be used in many different settings. CA learning environment, according to Collins (2006), embodies principles such as situated learning, communities of practice, scaffolding, articulation, and reflection. Though, the CA model is promising, it poses an asymmetric relation between teacher (expert) and the learner (novice) as if learning is unidirectional, during the period of interaction. This idea is fundamentally different from the phenomena of interactive learning that constantly recurs in the teacher – learner interactions, involving a relation of constant give and take.

The APU model for design activity

An influential model for teaching technology to students from primary through secondary levels has been the Assessment of Performance Unit (APU) (Kimbell et al. 1996). This was developed and used in a large scale project on assessment involving a large number of students in the UK schools. The model lays an emphasis on the design process, which is represented as a design loop in Figure 2.5. Designing, as described by the model begins with observations of the context and is driven by the need suggested by the context. The need leads to investigation of many potential alternative solutions which are eventually developed, refined and detailed. Prototypes and mock-ups mediate the translation of these ideas before the actual making happens. After making, students engage in evaluation of their products, a process seen as a metacognitive practice. In principle, the model affords for a lot of flexibility in pacing and ordering the activities. However, it has been observed that in practice the loop sequence gets translated into a stage model of design. One criticism of this approach is that design becomes a ritual, a formal practice to reach a finished product in a D&T classroom (McCormick, Murphy and Davidson 1994). Another critique of this approach is that aspects of technology which concern the consequences of a product for society, do not get discussed.

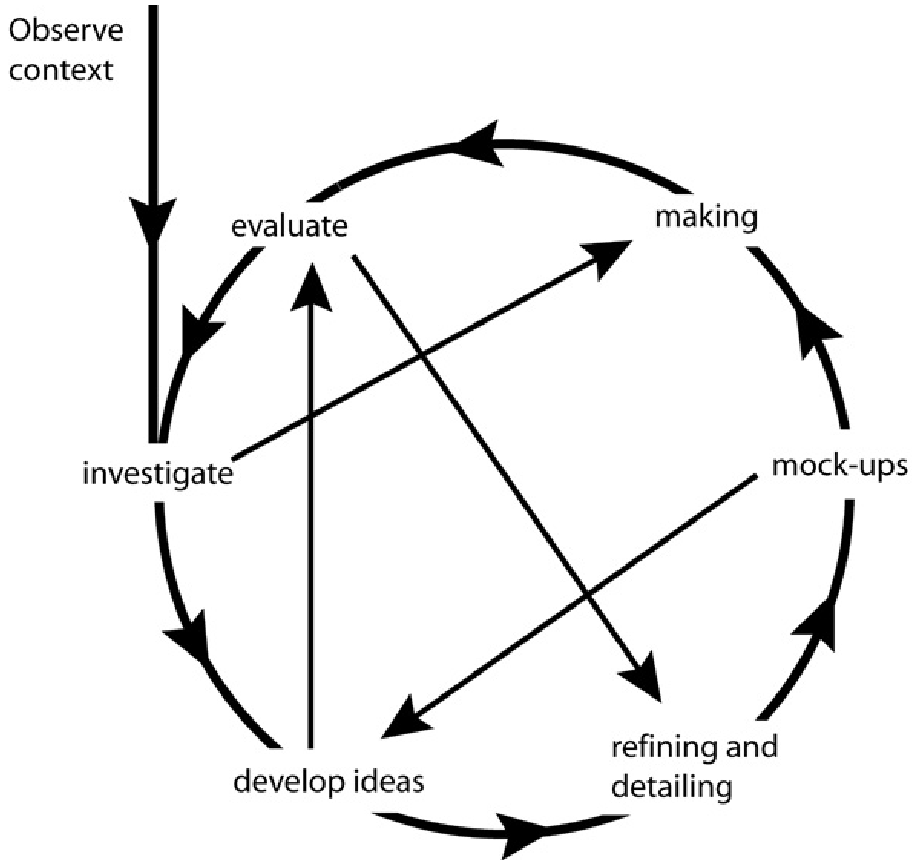


Fig. 2.5: An interacting design loop. Adapted from the APU model proposed by Kimbell et al (1996).

Summary of pedagogic models

Each of the approaches discussed above has some important pedagogic benefits for teaching technology, as well as some limitations. Besides, each model has value in an appropriate context of learning. An ideal pedagogical practice would not be radically different from the APU model while drawing insights from several other models as well. Thus, one looks for a critical synthesis of models used for teaching technology in schools.

2.7.4 Meaningful classroom interactions

The pedagogic models help structure teaching-learning units. Whatever may be the model chosen, classroom interactions need to be structured and planned to maximise learning. Among others, aspects of communication and collaboration deserve special attention.

Communication

Design and technology education units are best carried out by incorporating interactions among students, and between student and teacher. Explicating thought gives the teacher vital clues to students' progress in thought and action. Language is a means to communicate and plays an important role in exchange of ideas and thought. D&T units can integrate the richness of languages while students discuss the socio-cultural meanings of the artefacts they handle and activities they negotiate. In fact, D&T education is seen as a context for developing and honing multiple literacies (see Table 2.3) (Cross, Naughton and Walker 1986, Natarajan 2004).

Table 2.3: The forms of communication

Mode of communication	**Form of language**	**Productive element**	**Receptive element**
Oracy	Spoken	Speaking	Listening
Literacy	Written	Writing	Reading
Numeracy	Number	Number manipulation and calculation	Number appreciation
Graphicacy	Graphic	Sketching and map-making	Map and picture reading
Physiognomacy	Body and sign	Movement, dance and expression	Watching and interpreting

Collaborative learning

Collaboration in very simple terms, involves interaction of more than one individual. Often collaborative learning is confused with co-operative learning. From the viewpoint of our research, it is very important to distinguish between the two terms. Often co-operative learning implies decomposing a problem and distributing responsibilities of solution among members of a group. Thus, in practice, such work proceeds as a cluster of parallel initiatives among the participants, though the initiatives converge on a shared goal (Crook 1995). Hence such interactions have limited scope for interpersonal co-ordinations. In contrast to this, collaboration necessarily involves dialectical interactions in a group. Collaborative learning refers to a teaching method in which students, even those at various performance levels, work together towards a common goal. They are responsible for one another's learning and each student helps other students to be successful (Gokhale 1995). Collaboration cannot be enforced but can be encouraged through structuring suitable activities.

Design and technology involves the technical and cognitive processes of design. Working as a member of a team introduces different problems and possibilities for the designer, in comparison with working alone. Some arise because of the situation (structure of activity), while others are emergent or accidental (Cross and Cross 1995). A collaborative environment is one in which teacher takes the role of a facilitator who carefully guides and helps address problems throughout the engagement in a D&T education unit. Design and technology education units in implicit ways offers scope for cultivating an understanding of collaborative design as a process of learning and innovation where creation and negotiation of social practices and intermediary artifacts are a necessary part of the activity.

2.7.5 Classroom resources

An appropriate classroom interaction can be mediated through careful choice of classroom resources. Materials and tools are central to technology. Besides, the diverse approaches to technology education with its varying emphasis call for different kinds of resources. They are decided by the existing socio-economic and cultural milieu of the education system.

2.7.6 Socio-cultural aspects of learning

Cultural preferences and priorities shape the acceptance and extent of technology in a given context (Pacey 1983). In other words, technology is contextual. According to Rowell (2004), learning can be thought of as transformation of participation in the shared activities of the community. Students participate in shared activities as members of pairs or small groups, as well as in whole class activities. Students interact with each other and with the teacher, which comprise a community of learners where knowledge is co-constructed. Students share conceptual, material resources and appropriate tool related practices which has affinity with students' discourse of experiences prior to instruction.

2.7.7 Evaluation and assessment practices

Educators use two distinct but complementary processes: assessment and evaluation. Assessment provides feedback on knowledge, skills, attitudes, and work products for the purpose of elevating future performances and learning outcomes. Evaluation determines the quality of a performance or the outcome and enables decision-making based on the level of quality demonstrated. Assessment is for the student and the teacher in the act of learning – for judging performance. It provides feedback for improvement, while evaluation is usually for others – for judging quality. However, judging the performance of a product or a system (product/system evaluation) is very different from judging the performance of students. To evaluate means weighing up of one aspect of a problem against another.

According to Solomon and Hall (1996, p270), two comparisons are possible and useful: (i) with the pupil's original design drawing, and (ii) with the ultimate purpose of the artefact. The former is a rare find in primary technology. However, the test of an artefact to see how well it achieves its purpose is an equally valuable aid to evaluation. Such an evaluation, according to them, is the hallmark of technological endeavour and distinguishes it from its more abstract and less utilitarian relative, science.

2.8 Analyzing design and cognition

Of all aspects that have been researched, cognitive aspects are addressed in fewer studies. Research in cognitive aspects can give vital insights into suitable modification of learning at several levels.

2.8.1 Cognition through design drawings

Technological design problem-solving engages individuals in problem scoping. Real-life problems, as have been mentioned earlier, are indefinite. The problem is to be understood along with its constraints. Design, which is at the core of technology, involves anticipation of a visualised product. The product may be an artefact, a process or a system intended for a specific purpose. Visualisation involves imagery, mental animation and manipulation. Through an interplay of images in the mind's eye, grappling through the uncertainties, individuals try to think of possible solutions. The history of engineering drawings demonstrates that the modelling methods available to designers affect the potential content of their thoughts (Baynes 1992). Quite often, visualisation is mediated through tools such as gestures, drawings and verbal language. Verbal language demands an understanding of conventions and rules and its articulation which conveys the meaning implied. However, it is constrained by the need of knowing the language conventions in their contexts. Gestures on the other hand, though not taxing, are subjective and demand a lot of attention and labour to produce and attend to the signs conveyed. Besides, once lost it may be very taxing to retreat and communicate the meaning of a gesture. Drawing is a useful mediation which can serve a variety of functions without having to learn much of the conventions. Several levels of communication are possible with drawings, especially so in design. For one, design drawings are a means to externalise ideas about objects, parts, assemblies, motion, etc. Tversky (2002) notes that the public nature of sketches allows a community to observe, comment on, and revise the ideas, and enact those revisions in the external representation. In this sense, drawings facilitate collaborative work environments.

Depending on the purpose, people have variously classified design drawings. Lawson (2004), an architectural designer, has classified drawings based on their function as presentation, instruction, consultation, experiential drawings, diagrams, fabulous drawings, proposition and calculation drawings. From the view point of children's drawings, Hope (2003) has classified drawings to be of following kinds: picture, single-draw, multi-draw, multi-design, progressive and interactive drawings. In all its different contexts, design drawings evolve. They mediate thought and use of sketches in the early phase of design conceptualisation is common. Known by different names such as conceptual sketches, thinking sketches, etc. these mediate externalization of idea offloading memory (Bilda and Gero 2005). Besides, these may also serve as a source for inspiration through recombining sketched ideas into a practical form. Uncertainties and restructuring of ideas is possible through such an interaction (Verstijnen, Leeuwen, Goldschmidt, Hamel and Hennessey 1998). Explorations using sketches involve *interactive imagery* where designers are imaging a target configuration. Vygotsky (1978) believed that technical drawings are one of the psychological tools that mediate our learning, which we learn to use in our social interaction in the zone of proximal development.

2.8.2 Cognition in action (making)

During making, design ideas translate into tangible artefacts. Students engaged in making are thinking about materials and their transformation. Making involves imagery and mental manipulation which are mediated by materials. Imagining the consequences of actions such as folding, cutting and effects of the use of hammer or a cutter develops foresight among students. The proper (function intended by the designer) and accidental (function different from proper function, ascribed in the context of its use) functions of tools get appropriated through handling them. These are explicated while students reflect on their actions in a collaborative learning environment.

2.8.3 Cognition through reflective action

Cognition is not restricted to designing but extends well beyond making. Students, while designing, interact with their drawings and reason about structures of the components, their assemblies, and how an envisaged artefact will function. Design is an iterative process and the student designer is a reflective practitioner always interacting with the tools and resources (Schön 1983). When the student designer is the maker, continuous with the designing, reflection is enhanced and complimented by the action of making. The student is confronted with the consequences of design in a very tangible form (Kimbell et al. 1996).

After making, when the artefact or system has been realised, the student reflects on its performance. Students test their ideas through the different stages of making and reflect on the features that contribute to the functioning of the made product, which include identifying problems and discussing potential solutions.

2.9 Summary: Review of the literature

In this chapter, we have examined the factors that influence structuring classroom engagements for Indian middle school students. Beginning with the understanding of the terms *technology* and *design*, the need for a synergy of design and technology in education was discussed. The different approaches to technology education and the place of technology education in Indian schools have been explored. Technology is not a subject in the Indian schools. The critical aspects to be considered before introducing technology education at school level in the Indian context include the motivational concerns, knowledge, skills and values acquired or the content of technology units, pedagogical models, classroom interactions and resources, socio-cultural aspects of learning and evaluation and assessment practices. The tools needed to gather insights of students' cognition as they engage in D&T education unit have been reviewed. Besides cognitive aspects, a D&T engagement legitimises and values the verbal and non-verbal modes of expression. The critical aspects served as inputs for structuring our D&T education units.

Chapter 3

A study to probe middle school students' ideas about technology

This chapter presents the study of students' perceptions and attitudes towards technology. A survey study was conducted with Indian middle school students of class 8 (average age 13 years), in and around Mumbai, using a questionnaire. Beginning with reasons for pursuing an attitudinal study, the chapter discusses the objectives and methodology used for conducting the survey. The development of an instrument suitable for the Indian context, data collection, the framework for analysis and results have also been discussed. The chapter concludes by highlighting the salient findings from the study.

3.1 Why study attitudes towards technology?

Humans live in an environment surrounded by technological artefacts, which embody the knowledge and skills of their making and use. The artefacts may be tools, devices, machines or systems. Artefacts are used, modified and adapted for specific purposes. Technological activities modify the environment to meet human needs and desires, often using the artefacts (tools). In such a technology dominated world, which is changing and has influence on our lives, it is interesting to know how the term *technology* is perceived by people.

What we understand of technology comes through our direct interaction with existing technologies or vicariously through the media. Home, school and students' immediate environment are all spheres of learning activity where ideas about technology are formed. School students are influenced by their physical and social surroundings, by what they read and hear. They actively construct their own meanings of technology. They form a unique sample for investigating emergent ideas about technology.

Education aims at building informed citizens. Educators have emphasized the importance of tuning the curricula to the cognitive levels of students in order to achieve meaningful learning (Ausubel, Novak and Hanesian 1978). Understanding students' existing ideas about technology will provide insights for those developing curricula. A clear, comprehensive and viable conceptual framework of what technology is and how it can be taught is necessary to develop teaching-learning units on technology education (Todd 1987). Besides, an understanding of students' knowledge of and attitudes toward technology are pre-requisites to effective teaching about technology (Bame et al. 1993).

Given the diversity of geographical, social and cultural contexts and differential levels of technological engagements of Indian students, it is expected that the concept of technology will differ among school students. The contextual nature of the construct *technology* among diverse Indian socio-cultural settings was probed through a survey.

3.2 Objectives of the survey

The broad aim of the survey was to study middle school students' perceptions of and attitudes towards technology as manifested through their responses to questions and situations and the associations they make with objects, activity, knowledge and consequences of technology. The broad objective led to several research questions, which are listed below.

3.2.1 Research questions

The following questions addressed the broad objectives of research and guided the development of the instrument, administration and analysis.

- What does the term *technology* mean to students? What ideas, activities, occupations/professions, and consequences/effects do they relate to technology?
- Who do students see as users of technology? What locations do they identify as relating to technology?
- What artefacts do students rate as *low* or *high*? Do they consider some artefacts and activities as not technological?
- What values (attributes) do students associate with technology?
- What kind of school subjects and disciplines of study do students associate with technology?
- What consequences do students perceive of technology in different situations and occasions of their encounters with novel technologies?
- Do socio-cultural factors of students' setting influence their perception of and attitude towards technology?

3.3 Methodology

The sample selection for the survey study and the instrument development happened in an integrated manner. The survey involved choice of the target group, identification of a strategy for drawing the sample, development of the survey instrument and its administration and analysis of the responses.

The methodology developed to address the research questions aimed to satisfy the following criteria for the sample and the instrument:

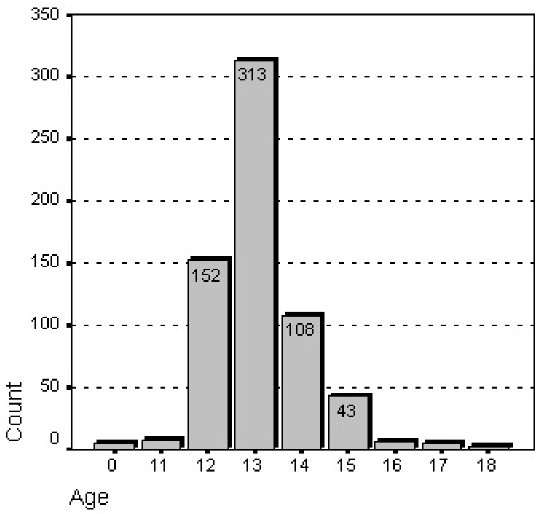
1. Include samples from urban and rural schools
2. Include the two media of learning used in a majority of schools in the State: English and Marathi (the official language of the State of Maharashtra).
3. Address all the manifestations of technology, that is, objects, activities, knowledge and volition.

4. Include location and context instances of objects, activities, locales, etc. that are common across the groups

5. Include diverse question formats: pictorial, open-ended, Yes/No, etc.

3.3.1 Sample

The survey was conducted in two phases: the pilot and the final study. The sample chosen for both phases were students of Class 8 (average age 13 years) coming from 14 different schools. The pilot survey was carried out in 3 schools that included an urban Marathi, urban English and a rural Marathi medium school. Figure 3.1 gives the age composition of the sample in the final study.



Age	Socio-cultural settings			Total
	Urban Marathi	*Urban English*	*Rural Marathi*	
0*	0	0	5	5
11	1	6	1	8
12	24	113	15	152
13	**157**	**113**	**43**	**313**
14	37	18	53	108
15	10	5	28	43
16	2	0	5	7
17	0	0	5	5
18	0	0	3	3

Note:* = age not mentioned

Fig. 3.1: Age composition of the sample in the final study

Rationale for choice of sample

Students are actively engaged in accommodating learning experiences. They form an ideal target sample for probing ideas about *technology*, a construct which is contextual. Engaging students in technology activities can be fruitful if we begin with an understanding of what students consider as technology. This is especially the case in India, where technology is not a subject in school curricula. Rennie and Jarvis (1995b) point out a significant problem in education. School children, who are in the process of learning, have limited language skills. Use of unfamiliar words in teaching and learning and teachers' use of specialist words which may have different colloquial meanings hold the risk of a potential mismatch of understandings, and can result in impaired learning. Therefore, it is important that teaching should allow shared meanings to be established, communicated and assessed. An understanding of what students perceive as technology, will help in designing an informed technology education curricula for the local contexts.

Students in Class 8 were chosen for a variety of reasons. Class 8 marks the end of middle school years and students have had some exposure to technology through media. The students, who are just two years away from school leaving, are able to articulate their thoughts and comprehend language better than in the earlier years. It is well established in literature that students younger than 10 years of age find it difficult to comprehend and give written responses to long questionnaires, especially open-ended questions (Rennie and Jarvis 1995b). Students have a repertoire of experiences of objects, activities, places and occupations from which they can recollect and associate. They can make independent judgements and voice their opinions freely. Besides, studies on students' ideas about science (Driver, Guesne and Tiberghien 1985), ideas about science and scientists (Chunawala and Ladage 1998), attitudes toward technology (Bame et al. 1993) and numerous other studies have shown that students of age 13–14 years (around 8 years of formal schooling) are an appropriate sample for surveying ideas through verbal modes.

Sample criteria and composition

The sample chosen to answer the research questions reflected the three criteria: (i) included more than one *socio-economic setting* (rural and urban), (ii) included the two most commonly encountered *media of formal learning* in the State of Maharashtra, namely, Marathi and English, and (iii) had a near equal representation of both the *sexes*.

The pilot study considered representative samples covering the three criteria so that difficulties of students from different kinds of contexts and sample types are addressed. Students' responses to the pilot questionnaire and a low number of *irrelevant* or *no* response categories confirmed the suitability of the questionnaire for the selected sample. The design and development of the questionnaire is discussed at length in later sections (refer section 3.4). Sample composition across the different contexts is summarised in Table 3.1.

Table 3.1: Sample composition for the pilot and the final study.

	Pilot (3 schools)							**Final** (11 schools)						
	Marathi			*English*			Total	*Marathi*			*English*			Total
	G	*B*	T	*G*	*B*	T	NT	*G*	*B*	T	*G*	*B*	T	NT
Rural	20	41	61	0	0	0	61	92	66	158	0	0	0	158
Urban	19	36	55	16	35	51	106	119	112	231	116	139	255	486
Total	39	77	116	16	35	51	**167**	211	178	389	116	139	255	**644**

Note: G=Girls; B=Boys; T=Total; NT=Net Total

A classroom of students in a setting formed a cluster. Using the convenience sampling technique, clusters were chosen to satisfy the three criteria of socio-economic settings, medium of learning and sex. Convenience sampling is a non-probabilistic method often used in exploratory research to get an estimate of the trends (Buddenbaum and Novak 2001). Relative physical proximity of the school to the researchers' workplace and an existing rapport with the school authorities also influenced the choice of clusters. The sample distribution in the final study with respect to the three variables studied is depicted in Figure 3.2.

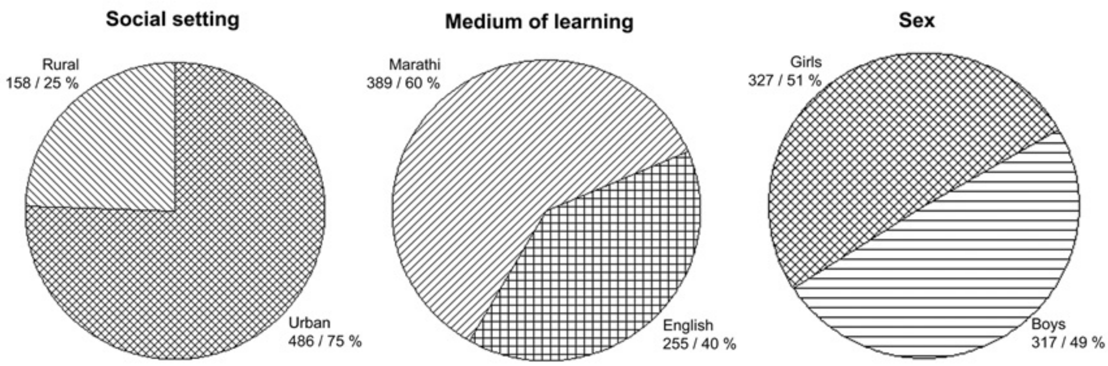


Fig. 3.2: Sample distribution in the final study for the three variables studied.

The sample mostly consisted of students from co-educational schools. Attempts were made to reduce gross imbalances between the number of boys and girls, while maintaining a balance in the number of Marathi medium and English medium students. Hence, two single sex schools in Mumbai and one in the rural region were also included in the sample in the final study. The urban sample had both Marathi and

English as the medium of learning, while there were no English medium rural (tribal) schools.

The socio-economic variable was operationalised in terms of the social setting of the schools (the social environs from which the school draws its students). Judgements of the socio-economic background are based on the interactions with principals/heads of respective schools and a general understanding of the social background gained through interaction with students.

3.3.2 Students' contexts

The socio-cultural background of the students had to be taken into account while designing the instrument to avoid bias to a sample type or a context. The background of students studied are discussed in terms of the urban-rural differences and similarities.

Urban-rural context differences

Urban schools were better equipped with facilities like library, laboratory, playground, sports equipment, furniture and toilets. Urban students had access to a variety of print (newspapers, libraries, posters and hoardings, etc.) and other media such as radio, television, and computer. Some even had access to the internet in the school or at home. Many urban students can and do avail regular guidance from educated parents and receive out-of-school tuitions for academics while some even pursue hobbies like dance, music, painting and singing. On the other hand, urban students generally face greater pressure to perform academically, finding little time for extra-curricular projects.

The rural sample in this study were from *Ashramshaalas* or residential tribal schools, run by the Tribal Welfare Department of the Government of Maharashtra. Tribes are minority groups listed in a government schedule and considered among the most socio-economically deprived people. *Ashramshaalas* are an endeavour of the government to educate the tribals and integrate them with the mainstream. The tribals, who have little educational background, generally make a living by marginal farming, agricultural labour, selling fire-fuel and minor forest products. The educational level of the parents of urban students, on the other hand, are normally higher than that of tribal parents and vary widely from middle school to post-graduation and beyond. The occupations the urban parents are engaged in show a much larger variety as well.

Rural students had limited access to information and resources. Textbooks were often the only printed matter they had. *Ashramshaalas* provide students with minimal needs of shelter, daily food and annual needs of uniforms, textbooks and notebooks. Classrooms double up as living quarters after school. Located in areas far removed from cities and towns, they experience frequent power shutdowns. Hence, electrical appliances like computers, though present, cannot be used. Their interaction spaces, limited to their school surroundings and nearby villages rich in natural environmental resources, have far fewer technological artefacts than do urban spaces.

Language is another point of difference between the urban and rural students. The spoken language in rural areas, including among the tribals, is the State language Marathi or its variant. Mumbai, which attracts a large migrant population, is cosmopolitan. The urban Marathi medium schools attract mainly the Marathi speaking students, while students of the English medium classes are a mix from a variety of linguistic backgrounds, sometimes as many as ten different home spoken (mother tongue) languages were found in a single classroom. English is taught as one of three languages in all schools in Maharashtra State, including rural and urban, as well those following a non-State syllabus (such as the syllabus of the Central Board of Secondary Education - CBSE). Marathi is taught only in schools following the State Board syllabus. Thus all students have some exposure to English, though the competencies differ widely.

In general, gender disparity is evident at all levels of education in all States in the country. In Maharashtra, a State with relatively lower disparity, in 1999 on an average, only 64.5 girls appeared for the school leaving examination for every 100 boys. A larger proportion of girls than boys drop out at every stage of school education. The gender disparity in rural classrooms is far worse than it is in the urban classrooms. This reflects in the literacy scenario in the two regions in our study. The percentage rural literacy rate in the Thane region in 2001, from which tribal students in the study come, was 71 for males and 58 for females. The corresponding percentage literacy rates in the urban region of concern to this study was 90 for males and 83 for females (Gov 2002).

Urban-rural context similarities

The similarities between the urban and rural students come largely from the context of their schools, which follow a similar educational content from textbooks. In fact, the Marathi medium schools, both urban and rural, follow the same textbooks that are prescribed by the State Government.

It is therefore interesting to compare the urban and rural (tribal) school students and to see how their varied exposure to technologies, their differing lifestyles and surroundings, and available resources influence their perceptions of and attitudes toward technology.

3.3.3 Towards designing an instrument

Literature review revealed that students' ideas about technology have been reported in studies representing a variety of contexts: students' ideas about science and scientists, the nature of relations between science and technology (Sjϕberg 2002) and linkages between science-technology-society (STS) (Aikenhead, Fleming and Ryan 1987). Only in the past two decades, with the emergence of technology education as a discipline in formal schooling, have studies focused their attention on understanding attitudes towards technology *per se*. Significant among them have been the Pupils' Attitudes Towards Technology (PATT) studies. In the Indian context, the few studies undertaken targeted the post school students (Rajput et al. 1990).

Over the years, the social scenario in India has changed because of the influx of technologies. Besides, technology being contextual, needs to be studied in the context of its use. An appropriate instrument that integrates questions on local contexts and encompasses technology and all its manifestations can be used to probe students' ideas. It is also hoped that taking into account Indian students' perceptions of technology will help in tuning the curricula to the cognitive levels of students in order to achieve meaningful learning (Ausubel et al. 1978).

Choice of a tool for probing students' ideas

A number of research tools can be used to probe ideas about technology: visuals and drawings, interviews, opinion polls, questionnaires, etc. Survey is an appropriate method that gives insight into the prevalent trends in the sample data and the general notions among a population. Survey research is an established technique in the field of education and has been in use since the 19th century (Creswell 2002). Survey researchers collect data using two forms: questionnaires and/or interviews. Both techniques have their advantages and limitations. For the purpose of exploring ideas about technology among urban and rural sample of students, a questionnaire form of survey was used. A questionnaire based survey is advantageous since large student sample can be included, an understanding of the general trends can be gained, is convenient and is potentially anonymous. Hence, survey was an ideal method for exploring the breadth of ideas pertaining to technology among students.

The nature of an instrument used for survey research normally depends on what the researchers want to probe, as well as on other instruments used earlier or in combination for probing. For example, the PATT questionnaire was developed based on the results of the interviews conducted with students (de Vries 1987). In another study, drawing and writing activities along with a questionnaire were used to probe students' ideas about technology (Rennie and Jarvis 1995b). In most cases, survey studies involve gathering responses to verbal/written questions. Aikenhead (1988) analysed ways of assessing student beliefs and found that instruments based on empirical findings were more reliable than those deduced solely from philosophical stances of science educators. Development of our instrument was initiated with empirical data gathered from a study using posters as a medium for eliciting students' ideas about technology.

The poster study, which was a part of the National Science Day activity at HBCSE, encouraged students in the age range 10 to 15 years to choose one among the two themes, *Images of Science* or *Images of Technology* and depict their ideas as posters (Mehrotra et al. 2003). Students portrayed technology mostly as a collage (collection) of stationary objects, especially those related to communication and transport (refer Figure 3.3). They often confused technology with science as evidenced in a poster by a student who chose the theme *Images of Science* but depicted artefacts (see Figure 3.4).

Fig. 3.3: A male student's depiction of technology as a collection of objects.

Fig. 3.4: Depiction of technological artefacts by a girl student who choose the theme *Images of Science*

Though the study using posters revealed some interesting findings, it was limited to urban students and involved subjective interpretations. We needed a study that could be used across different settings. Thus, insights from the poster study, literature on attitude studies and the philosophical notion of technology all contributed to the development of our questionnaire.

3.4 The questionnaire design

Developing an instrument in the form of a questionnaire that would be appropriate for the diverse sample chosen posed a challenge. The *slippery* nature of the term *technology* and the complexities of translating the term and associated terminologies into Marathi, contributed much to the difficulties. For example, the Marathi equivalent of the term *technology* is *tantra-dnyaan*, which literally translates to Instrument-Knowledge. Conscious efforts were made as far as possible to choose Marathi equivalents that were close in their semantics to English words and were common in usage.

The complex construct termed *technology* can be probed for its different aspects. Developing the questionnaire involved listing themes relating technology and aspects of students' lives: students' interests, the objects, activities, knowledge and skills they may associate with technology. Technology may be perceived as seen in urban or rural contexts, in homes, offices and other places, and be associated with males or females, rated as high or low, judged to be safe, easy, unsafe, difficult, etc. Technology may also be viewed as helping to attain certain goals either for individuals or for society. Technology can be seen to need certain knowledge and skills and these can be seen to be teachable or derivable from experiences. Specifically, in the case of students and teachers, it may be seen as being related to certain subjects taught in school or found in co-curricular and extracurricular educational materials. Besides, technology may also be manifested as "volition". Volition has a specific meaning in the philosophy of technology where it implies knowing the use of technology and recognising its consequences (Mitcham 1994). Based on literature and our understanding of technology, a scheme was developed that helped develop the questionnaire, formulate our research objectives and structure our analysis (refer Table 3.2). The scheme draws from the characterisation of technology in terms of its manifestations, in the philosophy of technology, discussed earlier in Chapter 2.

A survey questionnaire developed included items probing the perception of technology in specific situations, especially those relevant to the Indian context. Some items encouraged students to rate technological objects and activities. The questionnaire integrated a pictorial component as well. But, we are aware of some of the inherent problems of surveys through questionnaires. The responses are often constrained by the structure and monotony of lengthy questionnaires. Therefore, in order to

Table 3.2: Themes related to technology that were probed in the survey questionnaire.

Themes	What the theme probed
Technology and students' interests	Relation between technology and students' future plans and ambitions
Technology as objects (artefacts)	Students' ratings of level of technology in each of the given objects
	Association of technology with locations
Technology as activities	Students' ratings of level of technology in each of the given activities
Technology as knowledge	Judgements about prior technological knowledge helping one perform better in given occupations
	Students' choices of occupations as suitable for a male or a female
	Links between technology and knowledge, skills and school subjects
Technology and volition	Consequences and qualities attributed to technology, and uses and goals associated with technology at individual and societal levels
	Students' reactions to situations of technology change

overcome the problem, several kinds of question formats were used and subjective questions were included to evoke spontaneous ideas from students (de Vaus 1986). The items within each question were chosen to represent perceived gender, social setting and ratings of technology. Findings from the earlier study on students' drawings were used to generate the representative items.

3.4.1 Question formats and content

The questionnaire had 5 parts: (a) introduction, that also had guidelines to students on the structure of the questionnaire; (b) request for personal information such as, name, age, school and career choices; (c) a free response question (like an idea map) on technology; (d) ratings and other close-ended questions; and (e) pictures that had to be rated for the level of technology involved. The questionnaire was first developed in English (see Appendix A), the language of choice among the researchers and was then translated into Marathi. Realizing that the term *technology* is a complex, contextual construct, introduction to the questionnaire included one of the many dictionary definitions (Gove 1971), “Technology according to some is the art or science of applying scientific knowledge to practical problems.”

The pilot questionnaire had 14 major questions and 363 items. The question formats included context-free questions as well as situation-specific instances that we hoped would encourage judgements and opinions. The items in all question formats involved traditionally perceived stereotypes of both genders. They also involved different levels (high/low) of technology in rural and urban contexts. The variety of formats of questions used in the questionnaire are described below.

1. *Rating scales:* These questions formed the largest category and resembled the 3-point Likert scales. Examples of response options are - (i) Agree/ Unsure/ Disagree; (ii) No/ Low/ High technology. Example of a question:

III Technology in activities

What kind of technology is involved in the following activities (things we do)? Tick (√) *only one* cell in each row.

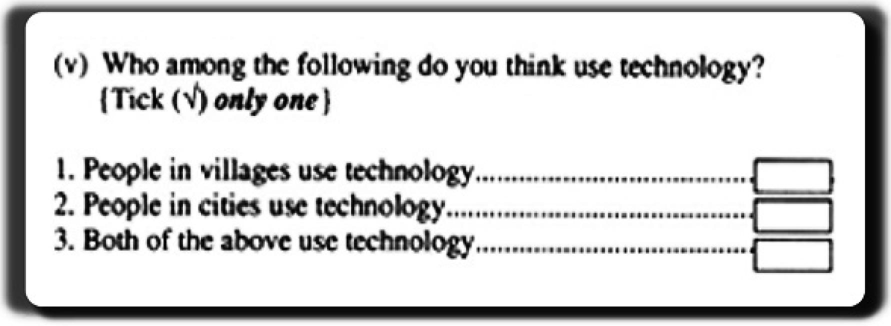
No.	Things we do	No Technology	Low Technology	High Technology
1	Playing games			
2	Making pickles			

2. *Questions with dual options:* Some questions allowed only for 2 possible responses, e.g. *Yes/ No* or *Agree/Disagree.* Where appropriate, such questions were accompanied by a relevant free-response (open-ended) question. Example:

(iii) To be considered technologically advanced, a nation must possess ....
{Tick (√) whether you “Agree”/ “Disagree”}

	Agree	Disagree
1. Nuclear power plants..		
2. Modern agricultural tools....................................		
3. Weapons..		
4. Food for all..		
5. Modern industries...		

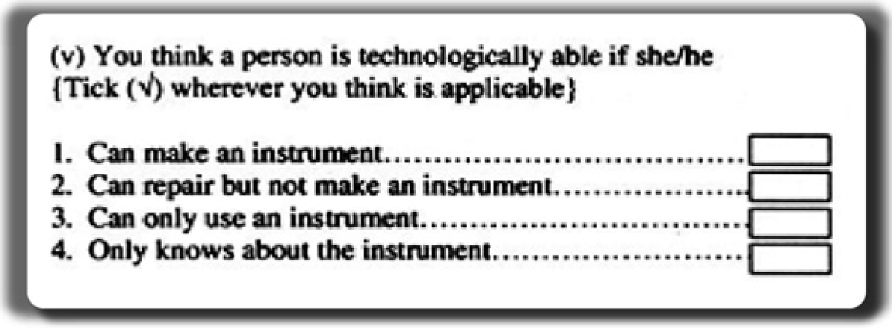
3. *Multiple choice, single response:* Students had to mark a single response that they thought was the most appropriate among the given 3 or 4 options.



(v) Who among the following do you think use technology?
{Tick (√) *only one*}

1. People in villages use technology....................................
2. People in cities use technology...
3. Both of the above use technology....................................

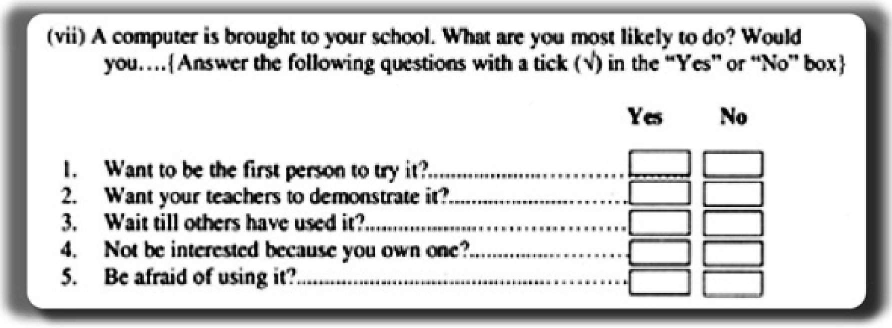
4. *Multiple choice, multiple response:* In the multiple response questions, the respondents could mark one, more than one or even all the options.



(v) You think a person is technologically able if she/he
{Tick (√) wherever you think is applicable}

1. Can make an instrument....................................
2. Can repair but not make an instrument...................
3. Can only use an instrument................................
4. Only knows about the instrument..........................

5. *Specific situational contexts:* In some cases, a scenario was constructed to elicit situation-specific responses, as in the question shown in the figure.



(vii) A computer is brought to your school. What are you most likely to do? Would you....{Answer the following questions with a tick (√) in the "Yes" or "No" box}

		Yes	No
1.	Want to be the first person to try it?		
2.	Want your teachers to demonstrate it?		
3.	Wait till others have used it?		
4.	Not be interested because you own one?		
5.	Be afraid of using it?		

6. *Open-ended questions:* A few open-ended questions were included in the questionnaire. For example, the idea map question "What ideas come to mind when you see/ hear the word technology?" The free-responses would complement the structured questions and provide some flexibility to the respondents.

3.4.2 Pilot survey

The pilot survey was conducted in June 2002 among students from an Urban Marathi medium school, an Urban English medium and a Rural Marathi medium school. The questionnaires were administered during school periods. The administration schedule is given in Table 3.3. Two persons, including at least one of the 4 researchers, were present during each administration. After handing out the questionnaire to students, a researcher read out the introduction and guidelines. The students took about an hour and a half to complete the pilot questionnaire, which included a total of 363 items. Some items, words and pictures posed difficulty in terms of familiarity and understanding and picture clarity. The doubts and difficulties of the students while they were responding to the pilot questionnaire were clarified and noted. The responses were coded and computerised. The pilot study enabled us to gauge suitability of questions in terms of the comprehension of meaning and students' understanding of the situations presented in the questions from their responses.

Table 3.3: Schedule for the pilot study

Sample type		**Single sex/Co-ed**	**Date**	**Number**
Urban	Marathi	Co-ed	17-06-2002	55
	English	Co-ed	21-06-2002	51
Rural	Marathi	Co-ed	29-06-2002	61
Total				**167**

3.4.3 Validity and reliability of the instrument

The questionnaire was evaluated for its validity before the pilot survey for several aspects:(a) overall design of the questionnaire, (b) appropriateness of language in terms of age and context, (c) cognitive and logical validity of content, and (d) clarity of pictures (Kerlinger 1983, Creswell 2002).

Five experts in the field of science/mathematics education, who are also science popularisers and textbook writers with experience in fieldwork and teaching in rural and urban areas scrutinised and validated the English and Marathi versions of the questionnaire. The versions were checked for their overall representation at lexical (use of words of similar difficulty) and semantic levels. The critical comments and suggestions of experts were discussed and incorporated in the English and Marathi versions of the questionnaire. The modified questionnaire was again whetted by the experts and then used for the pilot survey.

A preliminary analysis of the frequencies of responses in the pilot survey using Statistical Package for Social Studies (SPSS/PC+) software, showed up possible problems that students may have with the questionnaire. For instance, a large number of no-response from a sample cluster for a particular item showed that the item was unsuitable or not understood by the cluster. The problematic items and question formats were compared with the difficulties noted during the questionnaire administration. The questionnaire was reconstituted with the following changes:

- Items with words and phrases that were problematic were either dropped or their wording changed. Pictures of objects like thresher and vacuum cleaner were dropped because they were found to be equally unclear to urban and rural respondents.
- The language of some questions was simplified and illustrative examples were provided.
- In some of the question formats, students gave multiple responses when only one response had been asked. These question formats were suitably modified into statements with *agree*, *disagree* options.
- Within each question, attempts were made to have a balanced distribution of items addressing both boys and girls as well as the different socio-economic settings (as operationalised in Section 3.3.1).

Deletion of problematic items shortened the questionnaire to 259 items. The experts reviewed the questionnaire for representation of the researchers' intended content area and suitability for the chosen sample.

The questionnaire was tested for reliability using the *test-retest* method. This requires the sample to respond twice to a questionnaire: either to the same questionnaire or to two equivalent forms of the instrument (Creswell 2002). Since equivalence of the large number of items was difficult to ensure, the same questionnaire was used in the re-test (Norušis and SPSS Inc. 1990). Two different time intervals were used: a short interval of 14 days between test and retest, and a long interval of a year between the tests. The strategy for reliability test administration is given in Table 3.4.

Table 3.4: The test-retest reliability strategy

Interval	**Test sample**	**Interval between successive administrations**	**Re-test sample**	**Sample size**	**Range of correlation coefficients**
Short	Class 8	14 days	Class 8	38	0.91 – 0.99
Long	Class 8	1 year	Class 9	30	0.80 – 0.97

The two intervals helped rule out the alternative explanation that an individual's response in the first administration may have influenced the response in the later administration. For each time interval, reliability was measured by the correlation in the two administrations between the response trends to the same questions. The questionnaire, with a variety of question formats with varying number of items, could not be rated using an additive scale. Therefore the measure was used for items within each question. Six questions of the free response format or those with less than 10 items were not included in the reliability analysis.

The results of reliability analysis using the short and long time intervals for the 8 questions are given in Table 3.5. The questions with more than 10 items yielded a high correlation coefficient for both the time intervals: 0.91 – 0.99 for short interval and 0.80 – 0.97 for the long interval. The greater reliability coefficients in the short-interval case is not simply a case of recall of responses, as can be seen from the high correlation coefficients even after a gap of many months as in the long interval case.

Table 3.5: Results of reliability analysis for short interval (SI) and long interval (LI)

Ques. No.	**Nature of question**	**No. of items**	**Corr. for SI**	**Corr. for LI**
III	Technology in activities	35	0.95	0.81
IV	Choose an occupation	20	0.91	0.80
V	Effects of technology	15	0.96	0.94
VI	Locating technology	15	0.94	0.81
X	Qualities of technology	10	0.99	0.92
XI	Who should do what job	10	0.96	0.88
XII	Occupations and technology (professions and performance)	20	0.94	0.92
XIV	Things and technology (object pictures)	65	0.98	0.97

3.5 Administration, data collection and coding

The final survey questionnaire was administered using the same procedure as in the pilot survey to Class 8 students in each of the 11 clusters. As given in Table 3.6, of the 11 schools, eight were co-educational, while one was a Marathi medium boys' school, another a Marathi medium girls' school and one Marathi medium rural girls' school. Typically the administration of the questionnaire began with the researcher reading aloud the instructions to the respondents. Students took about an hour to respond to the questionnaire. All items in the questionnaire were given numerical codes.

Table 3.6: Schedule for the final study

School setting	**School type**	**Date**	**Students**
Urban Marathi	Co-ed	24-07-2002	65
Urban Marathi	Boys'	30-07-2002	71
Urban Marathi	Girls'	12-08-2002	65
Urban English	Co-ed	01-08-2002	40
Urban English	Co-ed	02-08-2002	93
Urban English	Co-ed	02-08-2002	69
Urban English	Co-ed	05-08-2002	53
Urban Marathi	Co-ed	06-08-2002	31
Rural Marathi	Co-ed	06-10-2003	58
Rural Marathi	Co-ed	25-11-2003	42
Rural Marathi	Girls'	25-11-2003	58
Total			**644**

The responses to 259 items in the final questionnaire, collected from 644 respondents, were coded as numeric codes, entered in a spreadsheet to generate a variable by case matrix. These were randomly checked before feeding into the computer. The computerised data was cross-checked randomly before analysis to ensure that the entering was reliable. Computational analysis of the data was carried out using the SPSS software to test the responses on various parameters discussed below and to reveal the response trends.

3.6 Framework for analysis

The data was analysed at several levels using a variety of statistical tools. The analysis discusses questions under the different themes given in Table 3.2. Except the first theme, the questions for all other themes have responses in nominal categories, which have been assigned numerical codes. Frequency of responses from all respondents to all items in such questions was analysed.

The influence of the 3 independent variables on the responses were analysed for each question under the theme. The three variables were settings, medium of formal learning and sex. Each variable had two values: Settings – Urban and Rural; Medium – English and Marathi, and Sex – Girls and Boys. Comparisons were made between the pair of values of each variable.

The frequencies of responses for each question and for each theme helped make systematic conjectures. In some of the cases, it was possible to confirm through inferential analysis the findings from the descriptive analysis. A summary of the statistical techniques used for analysis have been summarized below:

- All the items which had nominal categories of responses were analysed for frequency of responses. The descriptive statistics gave insights into the trends in responses and allowed comparisons across the pair of values for each of the 3 variables.

- Chi-square goodness-of-fit test was used as needed to judge the significance of the differences between the frequencies of responses for pairs of nominal categories.

- Chi-square test was used to verify whether there was a statistically significant difference between the distribution of responses from a pair of values for a variable (e.g. between urban and rural settings) for an item.

- t-test was used for testing the statistical difference between the mean responses from the pairs of values of the variables. For example, between the mean response on an item from English and Marathi medium students. For this study, the significant implies a value less than or equal to 0.01

- The means procedure was calculated for the means of the subgroups for the 3 variables studied and the one-way analysis of variance (ANOVA) yielded a F - statistic which indicated whether difference between the two subgroups was statistically significant.

- Exploratory factor analysis (EFA) of questions on objects, activities, technological knowledge and occupations, and consequences with measurable items more than 10 was conducted. EFA is usually carried out on questions with more than 10 items and when the data is ordinal. Responses to some of the questions used for EFA had an implicit order. For instance, the questions where students had to rate items as being of *No*, *Low* or *High* technology.

Exploratory factor analysis (EFA) is a set of statistical techniques used for inferential analysis. Using principal component analysis, it is possible to interpret the underlying factors without making any presuppositions or beliefs about the nature of factors. The technique reveals the minimum number of factors that explain the maximum amount of total variance. Appropriateness of the technique is verified by the Kaiser-Meyer-Olkin measure of sampling adequacy (KMO) and the Bartlett's test of Sphericity. All questions passed on both these tests, with a score greater than 0.5 for the KMO measure, and values that were $p<0.05$ on the Bartlett's test of Sphericity (Norušis and SPSS Inc. 1990). The items that associated on a common factor were compared with the mean values representing students' rating of the level of technology.

Findings obtained from the descriptive and inferential analysis have been consolidated and reported in the following section in terms of the manifestations of technology schematised in Table 3.2. These are:

- Technology and students' interests
- Technology as objects
- Technology as activities
- Technology as knowledge
- Technology and volition

3.7 Results and discussion

Each section begins with a description of the questions that are included under it. The influence of the three variables: Settings (Urban and Rural), Medium of learning (Marathi and English), and Gender aspects (Girls and Boys) have been discussed. Supportive affirmations were sought in the association of items on common factors in the factor analysis.

The comparison of data on the three variables allowed us to isolate those items on which differences can solely be attributed to one variable. For any question, a comparative account of differences on three variables was compared. For an item which was significant on just one variable (say, settings), and not on the other two variables (namely, medium and sex), the difference can be attributed entirely to the setting variable.

The highest number of *irrelevant* or *no* responses for any question or item were observed among the rural sample. These were maximum in the question on activities, where the sum of irrelevant (about 20%) and no responses (10%) was, on some items, as high as a third of the total rural student sample.

3.7.1 Technology and students' interests

Students had to write *the ideas that come to their mind when they see/ hear the word technology.* The number of spontaneous ideas listed per student to this open ended question among the urban students (6.95) was significantly more than that listed among rural students (6.39); $F = 9.537$, $df=1$, $p< 0.01$. This is no surprise, as urban students have a richer experience of the modern and complex technological world than do the rural (tribal) students.

Boys have been reported to have a greater exposure to material objects and handle them more often than do girls (Rennie 1987). In this study too, overall boys listed significantly more ideas per student (7.06) than did the girls (6.57); $F =10.124$, $df=1$, $p< 0.01$. Mean of the number of ideas related to technology listed by students in the different sample types is summarized in Table 3.7.

Table 3.7: Number of ideas related to technology per student given by students in the different samples

Variables	Subgroups	N	Mean	F-value	p-value
Settings	Urban	486	6.95		
	Rural	158	6.39	9.537	0.002*
Medium	Marathi	389	6.79		
	English	255	6.84	0.115	0.735
Sex	Boys	317	7.06		
	Girls	327	6.57	10.124	0.002*

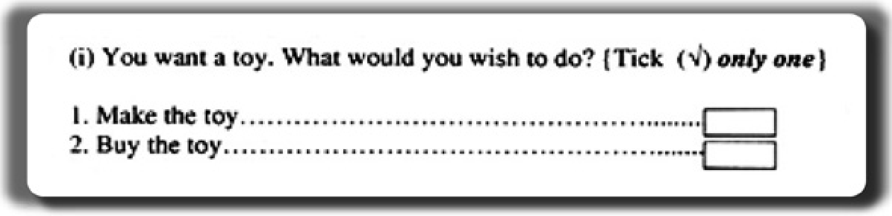
Note: * = significant difference

The nature of ideas listed by students give vital clues to the spontaneous associations that they made with the term *technology*. The question being an open-ended one invited several responses which were coded and categorised to get an idea of the general trend. The most frequent ideas that emerged were listing of artefacts, and abstract ideas such as information/knowledge/understanding.

Students' attitudes to technology are reflected in their aspirations and interests in areas related to technology. One of the initial questions, an open-ended one, asked students to describe their future career plans. Much like the earlier question, the range of plans for future were quite diverse for the urban than the rural sample. A large majority of students expressed their desire to pursue a career in medicine (doctor/nurse) or engineering (computer/aeronautical/automobile). The choice of these professions is a reflection of the stereotype existent among the society and the economic benefits associated with these professions.

A question asked students whether they needed to (a) know and (b) use technology in order to fulfil their future career plans. A large majority ($\gg 80\%$) of students responded that they needed to both know and use technology in order to fulfill their future plans. For the 3 variables studied, it was found that for any variable, a significantly greater number of students said that they needed *to know technology* than those who felt that they need *to use technology* in order to fulfill their career plans. Perhaps, this is a reflection of the Indian culture, where having knowledge is given relatively greater importance than applying knowledge or working with hands. The only exception were the boys sample, where there was no significant difference on χ^2 between *know technology* and *use technology* ($\chi^2 = 8.7171$,df=1,p=0.096). This indicated that similar proportion of boys thought that they need to know as well as use technology to fulfill their future plans.

One way of gauging student's interest in technology is through a class of artefacts that children love to interact with, that is, toys. The following question probed students' interest in technology through their preference for making or buying a toy.



(i) You want a toy. What would you wish to do? (Tick (√) *only one*)

1. Make the toy.. ☐
2. Buy the toy.. ☐

Most students across all settings chose to make a toy rather than buy one from the market as shown in Figure 3.5. The finding suggests that students are willing to engage in design and making activities, if they are motivated by an appropriate context. Khanna (1993, p1-3) while arguing for the significance of toys asserts that the process of making and playing with toys introduces children to ideas of experimentation, discovery and creativity in a subtle yet effective manner. Toy has both cognitive and affective aspects for students and hence served a useful contextual probe.

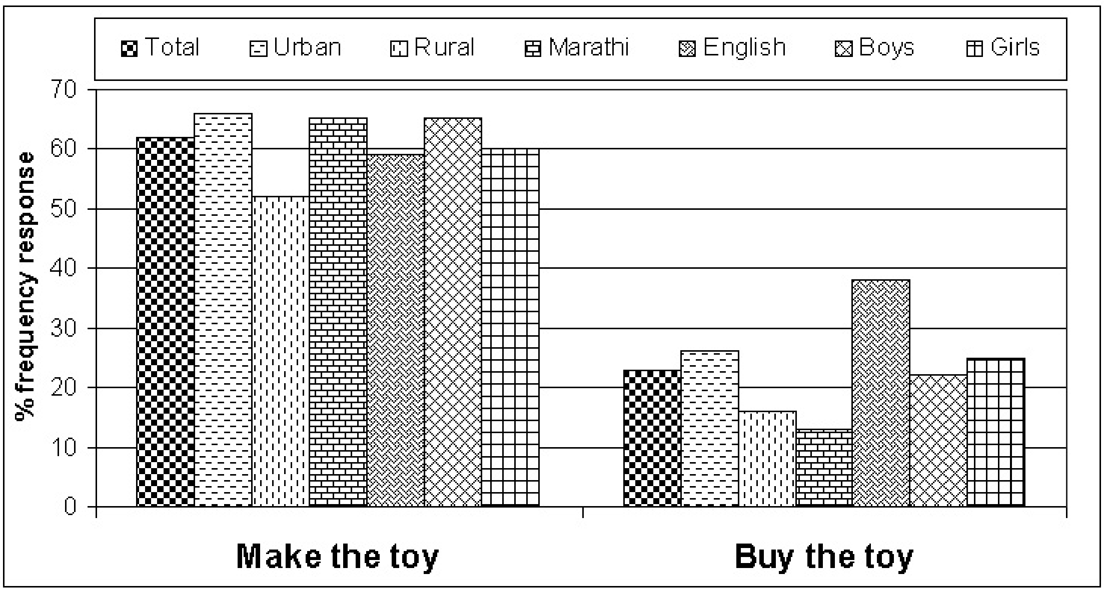


Fig. 3.5: Students' responses to a need situation.

Interestingly, urban students felt that that not all people can create technology. Their skeptic opinion emerged from the differences in response to a question, "Can all

Table 3.8: Significance test for comparing students' response on whether all people can create new technology.

Variable	Type	N	χ^2	df	p-value
Setting	Urban	485	14.097	1	0.01*
	Rural	144			
Medium	Marathi	374	4.454	1	0.04
	English	255			
Sex	Boys	315	0.13	1	0.908
	Girls	314			

Note: * = significant difference

people create technological things (objects) or make new technology?". Table 3.8 gives a summary of the differences on χ^2 test.

3.7.2 Technology as artefacts

Artefacts are defining features of cultures and their evolution. Humans perceive and interact with a wide variety of objects, which in turn influence thoughts and actions. Volk (2007, p191) cogently explains the profound influence of technological objects in our lives when he says, "Whether a simple object such as a crayon used in child's early learning experiences to more complicated and robust learning later through computers, the affective (emotions and motivation), behavioral (actions) and cognitive (thoughts) components of attitudes are impacted by the direct use or indirect association with the technological object." The perceived relation of objects and technology was studied through the following two questions:

- A question presented a table with list of 65 pictures of objects. Each row of the table had an item — its picture, a word label, and three columns for high, low or no technology options, one of which students had to tick. In the Marathi questionnaire, in order to retain the semantic association of a word label to the object, the English label was written in devanāgarī script with the Marathi label given in brackets (For example, *ladau (fighter) plane*, *vatanukulan yantra (air conditioner)*. Students responded with a tick mark for each item and indicated the level of technology in each object as high, low or none. The objects listed in the question were chosen such that they related to one of the 10 categories:

Office, Household, School, Agriculture, Sports, Warfare, Music, Transport and Workplace. These categories represented both rural as well as urban contexts and had objects familiar to both settings.

- Another question asked students whether technology was used in the given list of locations. Locations embed artefacts. Students' perceptions of objects and locations are therefore discussed together.

Each response in the objects question was numerically coded: tick on *no technology* was coded as 1, tick on *low technology* was coded as 2, and tick on *high technology* was coded as 3. The irrelevant response and no response were coded as 4 and zero respectively. These were noted for each item, but were not considered for the calculation of mean response. The mean value for each item from a sample reflected the average technology rating of that sample for that item. The means from the entire sample for the 65 items are arranged in descending order and shown on a plot of means versus objects in Figure 3.6. On the same plot area, the means for urban, rural, English, Marathi and Boys and Girls are also shown.

The plot for the mean values of the entire sample is continuous and monotonic. For an item, a mean value of 3 indicates that all respondents chose the *hi-tec* option for the item, a value of 2 indicates that all chose *lo-tec* option, and a value of 1 indicates that all chose the *no-tec* option. The standard deviation of means for all items ranged from 0.38 to 0.70. One can say that mean values greater than $2 + 0.6$ would surely reflect a choice of *high technology* for an item by the sample. Similarly, mean values less than $2 - 0.6$ would indicate a choice of *no technology* for an item by the sample.

On the basis of the above analysis, 14 objects were found to be rated by students as involving *high* technology. Typically, the electric or electronic and petroleum fuel-run objects were rated as involving *high* technology. Sports artefacts such as carom-board, drum, hockey stick, etc. and domestic kitchen equipments in the household category like the winnowing pan, roller and platform, lemon squeezer, etc. were rated as not involving technology. Musical instruments were also perceived as *no/low technology.* These figured very low on the mean value plot. However, no radical shifts were noted from *low* to *no* technology in the trendline. The means for the overall sample hide differences across settings, medium of learning and between boys and girls. These come to surface with a t-test which compares pairwise the variable values. It was

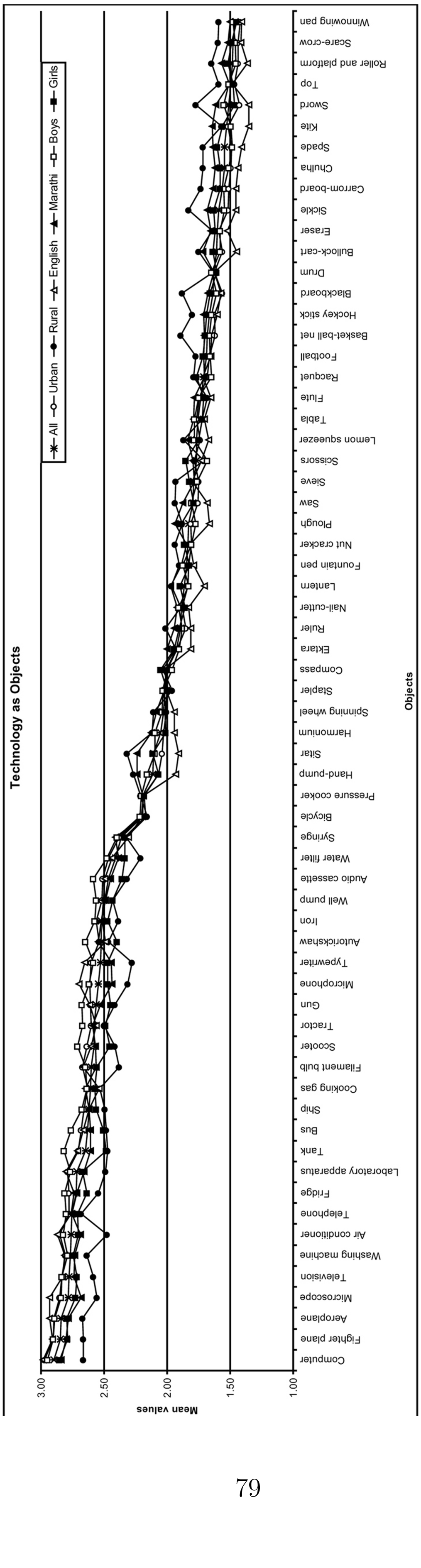


Fig. 3.6: Means for the 65 objects rated by students.

interesting to find that about a fourth of the objects (16 out of 65), did not show any significant difference on the three variables of settings, medium and sex. This included a large chunk of items rated as *low* or *no* technology such as fountain pen, stapler, compass, racquet, top, drum, tabla, football, bicycle, nail cutter, nut cracker, pressure cooker, cooking gas, syringe, telephone and scare-crow.

Urban and rural settings

The mean values for urban and rural samples converge only at three object clusters on the plot (see Figure 3.7). For objects that are rated as high technology, that is, mean values higher than 2.6, the mean values for the rural sample are consistently lower than the corresponding code values for the urban sample. However, the opposite is true at the lower end of the code values. Because of the lower values for the rural sample, only 5 items have values higher than 2.6.

The lower rating of the rural sample at the high technology end could have arisen because of the unfamiliarity of some of the objects among some students in the rural sample. Perhaps, a similar factor for urban students could have influenced their lower rating for items at the lower technology end. It could have been compounded by more rural students considering these items as higher technology as the item is the only one available for use in their environs. For example, air conditioner was rated by a significantly greater proportion of urban students as involving *high technology* than the rural sample. On the other hand, spade was rated by a significantly greater proportion of rural students as involving *low technology* than the urban students.

The differences in ratings for 10 out of the 65 objects, can entirely be attributed to the setting variable. These 10 objects are listed in Table 3.9 with their t-values. The power-driven objects which had significantly greater mean for the urban than for the rural sample included washing machine, filament bulb, and iron – all require electricity while ship is petroleum-fuel driven. On the other hand, the other six objects have a significantly higher mean for the rural sample as compared to the urban. The trend suggests that the ratings of objects were influenced by the contexts in which the objects were situated. Urban students with greater exposure to technological world were able to discriminate the objects as involving *low* or *no* technology more than the rural students.

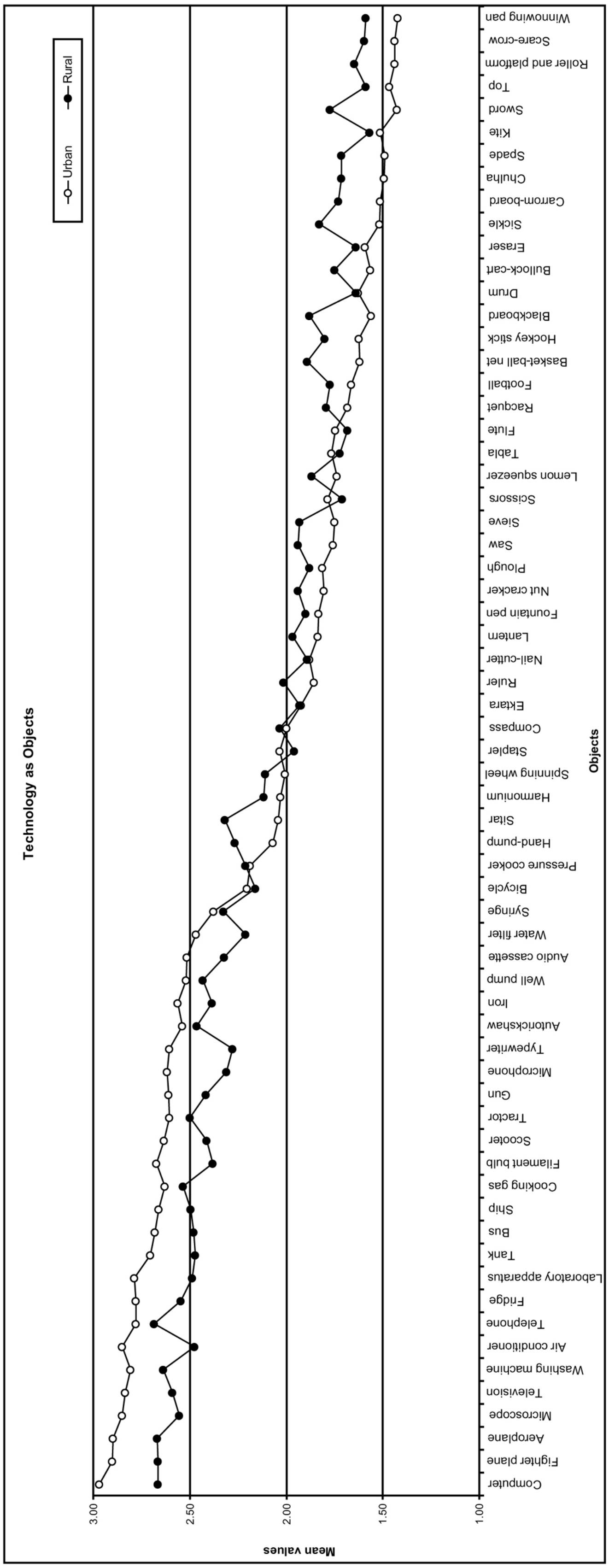


Fig. 3.7: Comparison of mean values for the objects on the setting variable.

Table 3.9: Object rating differences attributed to the setting variable

Objects	Setting	N	Means	S.D.	df	t-value	p-value
Washing machine	Urban	483	2.81	0.468	630	3.104	0.002
	Rural	149	2.64	0.606			
Filament bulb	Urban	483	2.67	0.555	633	4.745	0.001
	Rural	152	2.38	0.690			
Iron	Urban	484	2.56	0.567	630	3.291	0.001
	Rural	148	2.39	0.589			
Ship	Urban	484	2.66	0.562	628	2.540	0.012
	Rural	146	2.49	0.726			
Blackboard	Urban	485	1.56	0.667	631	-4.927	0.001
	Rural	148	1.88	0.746			
Ruler	Urban	481	1.85	0.683	627	-2.463	0.014
	Rural	148	2.01	0.700			
Basket-ball net	Urban	485	1.62	0.659	632	-4.256	0.001
	Rural	149	1.89	0.772			
Hockey stick	Urban	485	1.62	0.668	635	-2.807	0.005
	Rural	152	1.80	0.755			
Sieve	Urban	485	1.75	0.619	632	-3.078	0.002
	Rural	149	1.93	0.704			
Winnowing pan	Urban	485	1.42	0.561	634	-2.819	0.005
	Rural	151	1.59	0.656			

Note: For all items, $p<0.01$

Interesting differences were revealed when comparing two objects with the same function like the hand pump and the electric well pump. They are both used for lifting water. A significantly greater proportion of rural students, for whom the hand pump is source of water for daily requirements, perceived more technology in the hand pump than did the urban students ($t(624)=-3.251, p<0.01$).

English and Marathi medium

In most cases, the mean rating of the Marathi sample was greater than the rating of the English sample. Differences on eight objects could entirely be attributed to the medium variable. The objects that showed a significant difference exclusively on the medium variable are listed in Table 3.10. All these objects were rated by a large proportion of students as not involving technology. The difference between the English and Marathi sample thus seems more to be a matter of degree than any qualitative difference in perception of the English and Marathi students as far as objects are concerned.

Table 3.10: Object rating differences attributed to the medium variable

Objects	**Setting**	**N**	**Means**	**S.D.**	**df**	**t-value**	**p-value**
Ektara	Marathi	371	2.00	0.641	621	3.802	0.001
	English	252	1.81	0.536			
Flute	Marathi	378	1.78	0.652	631	2.455	0.014
	English	255	1.65	0.633			
Harmonium	Marathi	383	2.13	0.618	636	3.950	0.001
	English	255	1.94	0.547			
Eraser	Marathi	377	1.66	0.638	628	2.570	0.010
	English	253	1.52	0.640			
Lantern	Marathi	381	1.97	0.648	633	5.174	0.001
	English	254	1.70	0.638			
Plough	Marathi	382	1.94	0.690	633	5.051	0.001
	English	253	1.66	0.662			
Kite	Marathi	381	1.64	0.695	634	5.760	0.001
	English	255	1.35	0.569			
Spinning wheel	Marathi	378	2.09	0.656	630	2.796	0.005
	English	254	1.94	0.629			

Note: For all items, $p<0.01$

Boys and girls

Boys and girls had similar ratings for most of the objects. Only four objects, namely; autorickshaw, tractor, well-pump, and scissors showed statistical significance, which could be attributed entirely to the different perception by girls and boys. It is interesting that of the 65 objects, boys and girls had similar ratings for most objects indicating greater similarity than differences. More boys than girls perceived technology in objects such as autorickshaw, tractor and well-pump as indicated by a significantly greater mean value for boys. On the other hand, girls perceived scissors as more technological than boys, an object which is a tool and more often used by females than males. Perhaps, users identify an object as technological more readily than non-users. This has important implications for education as well. People who engage with technology may be able to value and appreciate technological products better.

Technology and locations

The question on locations had a list of 10 different locations covering various contexts of technological interactions. For each location, students had to indicate with a tick mark whether the given location involved any technology or not. *Don't know* was also a possible option. Each response in the location question was numerically coded: tick on *yes* was coded as 1, tick on *don't know* was coded as 2, and tick on *no* was coded as 3. The irrelevant response and no response were coded as 4 and zero respectively. These were noted for each item, but were not considered for the calculation of means. Though the responses are nominal categories, the mean value for each item from a sample reflects the inclination towards a *yes* or a *no* response. The mean values from the entire sample was plotted for the 15 locations. On the same plot area, the means for urban, rural, English, Marathi and boys and girls are also shown in Figure 3.8.

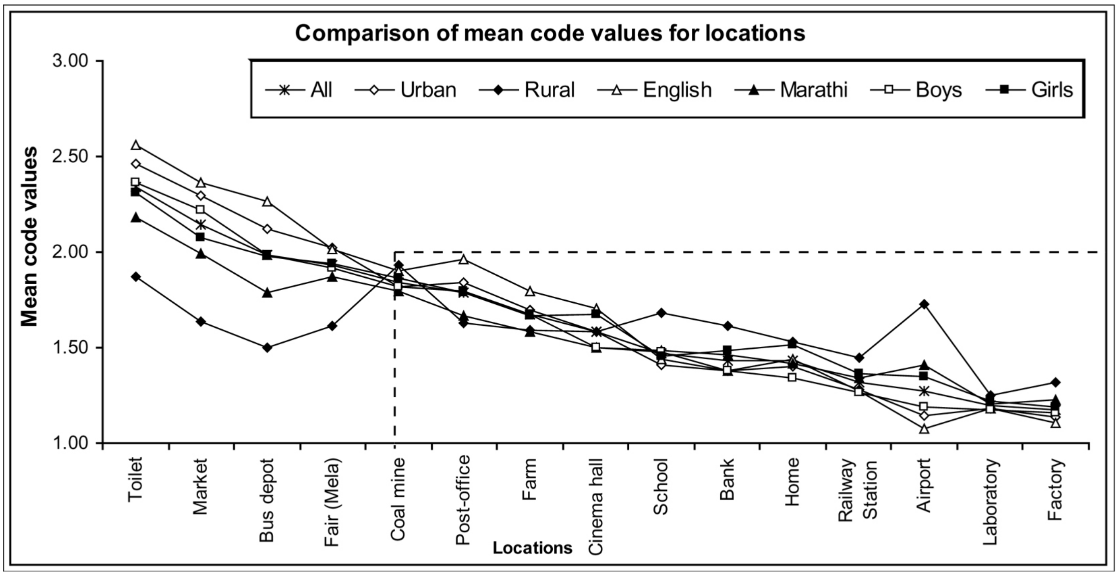


Fig. 3.8: Mean values for the 15 locations.

In the plot of mean values, the higher the mean value the lower the perception of technology in these locations. All values that lie in the range of mean values between 1.0 and 2.0 are perceived by students as locations that use technology (see trend-lines in the dotted box in Figure 3.8). Similarly all values above 2.0 indicate that technology is perceived as less/not used in those locations. The trendline for the entire sample shows that the mean values of the 2 locations, toilet and market, are above 2.0 indicating that these locations are definitely perceived by the sample as not involving technology. The mean values for laboratory, factory and railway station are lower than 1.50 and these were perceived as locations involving technology. The means for the overall sample however may conceal the differences across settings, medium of learning and between boys and girls.

Urban and rural settings

The means plot for the setting variable shows a marked difference in the trendline for the urban and the rural sample. While the urban sample has mean values ranging from 2.45 to 1.20, the rural sample shows a trend with a narrow range of values lying between 2.00 to 1.25 (see Figure 3.8). In the case of urban sample, the differences on locations considered as involving technology were distinct. However, the rural sample were not able to distinguish clearly the technology available in the locations.

Differences between settings were significant for all locations except for a 'laboratory' and 'coal mine'. Laboratory, where science activities happen are equally familiar to urban and rural students and had an almost similar proportion of urban and rural students choosing it as a location involving technology. On the other hand, coal mine is an unfamiliar location for most students in all the samples, as indicated by almost a third of the students choosing the *don't know* option. Coal and coal mines get covered in the curricula for Class 8 in chapters on Energy and Natural resources, in both National and State Board textbooks prescribed by the National Council for Educational Research and Training (NCERT) and the Maharashtra State Board, respectively. The students however seemed unaware of the nature of the activity and hence may have found it difficult to visualize a coal mine.

It is interesting to note the majority of students perceiving technology in locations such as market (U:30%, R:53%), bus depot (U:36%, R:54%), fair (U:40%, R:51%) and post-office (U:42%, R:46%) was more in rural than in the urban sample. In an age of internet and cellphone technologies, communication through letters has declined, more so in the urban regions. On the other hand, a significantly greater number of urban students in the sample saw technology in school, bank, airport and railway station. The trendline of mean values for the rural sample shows high mean values (that is, perceived as involving no/low technology) for 3 locations: toilet, coal mine and airport (see Figure 3.8). The higher mean value for the location toilet was consistent with the urban sample, who also considered toilet, market and bus-depot to have higher mean values and considered these locations as not involving technology. Laboratory and factory, on the other hand, were locations perceived as involving technology.

English and Marathi

For most locations, the Marathi sample perceived technology more in the locations than the English students. The only exceptions being airport and factory where a significantly greater number of English students see technology in these locations as compared to the Marathi sample. The significant difference on the location airport calls for special attention. Airports/factories are more often found in the urban areas and rarely in the rural locales. Rural students have hardly heard about, read or visited an airport or a factory. On the other hand, most English medium students were familiar with factory and airports and perhaps many had been to one. Responses to this question, more than others, reflected the influence of social settings, students' familiarity with locations, besides their perceptions of technology in familiar places.

Boys and girls

Both boys and girls perceived technology in similar locations. While both, boys and girls consider 'Home' as involving technology, the proportion for boys was higher than girls, as inferred from a significant difference on the t-test with a value of $t(619)=-2.938, p<0.01$.

3.7.3 Technology as activities

Much like the question on objects, the question on activities required students to rate a list of 35 activities as involving *high*, *low* or *no* technology. The items represented diverse contexts (urban, household, collective-work, etc.) and a range of human activities from diverse domains such as mechanical, manual, aesthetics, etc. Differences were noted in the response trends for the three independent variables, namely; socio-economic setting, medium of instruction in school, and gender.

The question on activities was in the form of a table. Each row of the table included an item, an activity presented as a phrase, and three columns for *high*, *low* or *no* technology response options, one of which students had to tick (see Appendix A). Response to each item in the question on artefacts was numerically coded: tick on *no technology* was coded as 1, tick on *low technology* was coded as 2, and tick on *high technology* was coded as 3. The irrelevant response and no response were coded as 4 and zero, respectively and these response codes were eliminated from further analysis.

As in the case of objects, the means from the entire sample for the 35 activities were plotted and on the same plot, the means for urban and rural, English and Marathi, and Boys and Girls were also plotted (see Figure 3.9).

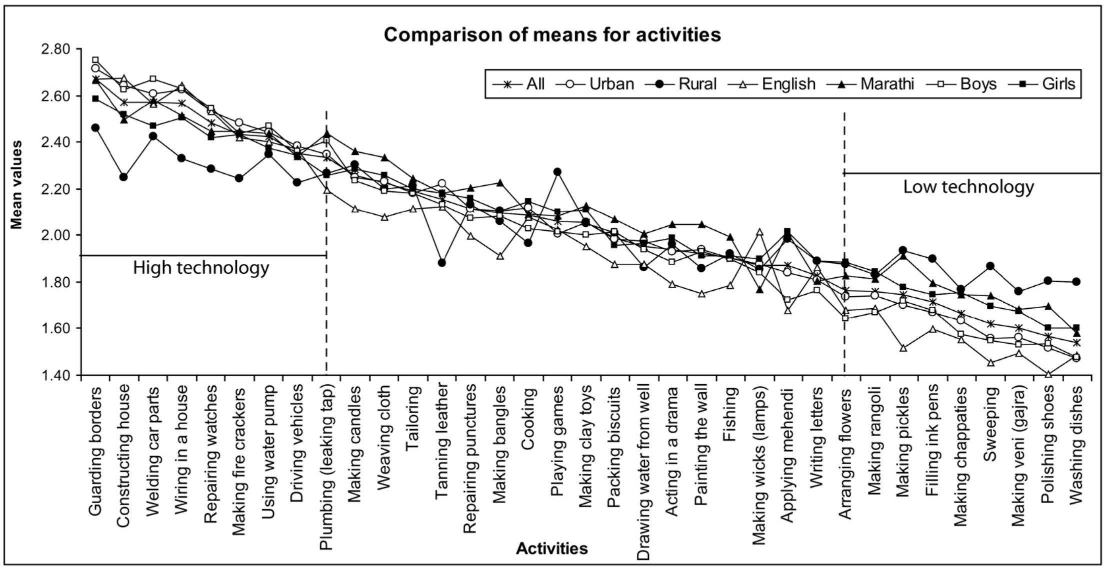


Fig. 3.9: Mean values for the 35 activities rated by students.

The standard deviation of means for all items ranged from 0.63 to 0.82. Hence, one can say that mean values greater than $2 + 0.6$ would indicate a choice of *high technology* for an item by the sample. Similarly, mean values less than $2 - 0.6$ would indicate a choice of *low/no technology* for an item by the sample. However, the mean values for most activities fall between 1.4 and 2.6. The plot for the entire sample is an undifferentiated one. However, a close look reveals a region with high mean values at one end, another end with very low mean values and an intermediate region as seen in Figure 3.9.

The 9 activities which had high mean values were those that require a formal orientation for acquiring specialized manual (dexteral) and professional training, either in handling or making artefacts. Besides requisites of specialized skills, these trades use specific tools, artefacts or gadgets, which distinguishes such activities from a range of other activities. Example of activities perceived as involving *high technology* were guarding the borders of the country, constructing a house, welding car parts, wiring electrical connections in a house, repairing watches, making fire crackers, drawing water using an electric pump, driving vehicles and plumbing (fixing a leaking tap). Region with high mean values included activities rated as *high technology* by a large proportion of total sample (e.g. guarding borders, welding parts, etc.). Region with low mean values coincide with activities rated as involving no or low technology. (e.g. washing dishes, polishing shoes, etc.)

Urban and rural settings

The mean values for activities rated as *high technology* were greater for urban as compared to the rural sample. On the other hand, activities rated as *low technology* had higher mean values for the rural sample as compared to the urban sample (see Figure 3.10).

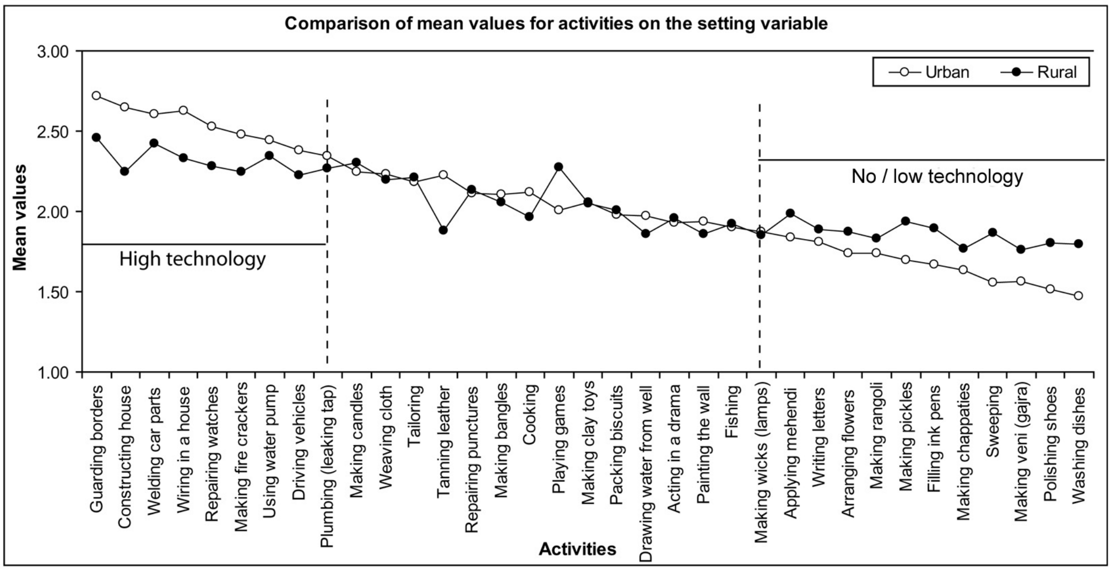


Fig. 3.10: Comparison of mean values for the 35 activities on the setting variable.

The mean values for the urban sample ranged from 2.80 to 1.50, while the trendline for the rural sample included many kinks and covers a narrower range of mean values ranging from 2.50 to 1.80. The mean ratings of the total sample was dominated by the urban sample, which can be noted in Figure 3.9, where trendline for the total sample is closer to the trendline of the urban sample.

The activities rated by both the urban and the rural sample as involving *high technology* included guarding borders of a country, constructing a house, welding car parts, wiring electrical connections in a house, repairing watches, making fire crackers, drawing water using an electric pump and driving vehicles. Of these, drawing water using an electric pump was the only activity which was not significantly different between the urban and rural students. This is much in line with our observation with the objects, where the difference between the urban and rural sample for the electric pump was found to be non-significant. A plausible reason may be extracted from students' interaction with such an object. Urban students living in multi-storeyed building have pumps installed to pull the water to the top floors while the rural students often work in farms which use a pump to irrigate the land. Students from both settings were familiar with the functional significance of the object.

Constructing a house received significantly lower mean values in the rural sample as compared to the urban sample. Rural students live in houses often build by the family with the help of local personnel and materials. On the other hand, urban students who mostly live in multi-storey buildings, see professionals like architects, engineers and semi-skilled masons construct them using a variety of modern equipment and structural materials, rated the activity as *high* technology.

Other items which showed a difference on the setting variable included playing games, washing dishes, repairing watches, tanning leather, making fire crackers and wiring electrical connections. These activities that showed significant differences in their mean values exclusively on the setting variable are given in Table 3.11. Some of the plausible reasons for the differences for a few activities are explained.

Tanning leather showed a dip in the trend line for the rural sample while playing games showed a peak. Both these activities hint to the role of context in the perception of technology. It was noted that more rural students rated tanning leather as not involving any technology than the urban students. The familiarity of urban students may have influenced students' ratings. *Dharavi*, which is Asia's largest slum dwelling and also houses a number of small-scale leather workshops where tanning is a regular phenomena, is a location known to urban students.

Playing games was rated by the rural students as involving *high technology* while the urban students who play with a range of gadgets and have access to a variety of sport equipment rated the same activity as involving *low technology*. Rural students do not have access to sport equipment and quite often use local resources such as the tree trunks to serve as their playing equipments. The scarcity and limited access to equipments perhaps make such technological activities to be perceived as involving *high technology*.

Table 3.11: Activities for which differences are attributed to the setting variable

Activities	**Setting**	**N**	**Means**	**S.D.**	**df**	**t-value**	**p-value**
Playing games	Urban	481	2.00	0.674	600	-3.343	0.001
	Rural	121	2.27	0.816			
Washing dishes	Urban	473	1.47	0.679	595	-4.742	0.001
	Rural	124	1.80	0.698			
Tanning leather	Urban	475	2.22	0.709	591	4.121	0.001
	Rural	118	1.88	0.829			
Making fire crackers	Urban	474	2.48	0.704	591	2.922	0.004
	Rural	119	2.24	0.813			
Repairing watches	Urban	477	2.53	0.672	588	2.983	0.003
	Rural	113	2.28	0.818			
Wiring electrical connections	Urban	472	2.63	0.633	582	3.689	0.001
	Rural	112	2.33	0.787			

Note: For all items, $p<0.01$

English and Marathi medium

The trendlines for the English and Marathi sample were almost similar. The mean values for the English sample is lower than the Marathi sample for most (27 of 35) of activities, that is the English sample rated low or no technology more than the Marathi sample. Only 2 activities showed a mean value significantly higher for the English sample as compared to the Marathi sample. These were constructing a house, and making wicks (for a lamp) as indicated by the circled mean values in Figure 3.11.

Boys and girls

The trendlines of mean values for the boys and girls sample are almost visually alike as can be noted in Figure 3.12. Of the 12 activities with a mean value lower than 1.9, 05 of them were found to be significantly different. These are domestic chores, carried indoors and do not require electricity. These include activities such as making *rangoli* (decorative patterns on house floors), etc. In the Indian context, these activities are mostly done by girls. On the other hand, outdoor activities usually pursued by men were seen by a larger proportion of boys as involving technology than did the girls. Thus, significantly greater number of girls perceived those activities which they regularly engage in as involving technology more than did the boys and vice versa. Engagement or familiarity seems to dictate the extent of technology perceived in an activity.

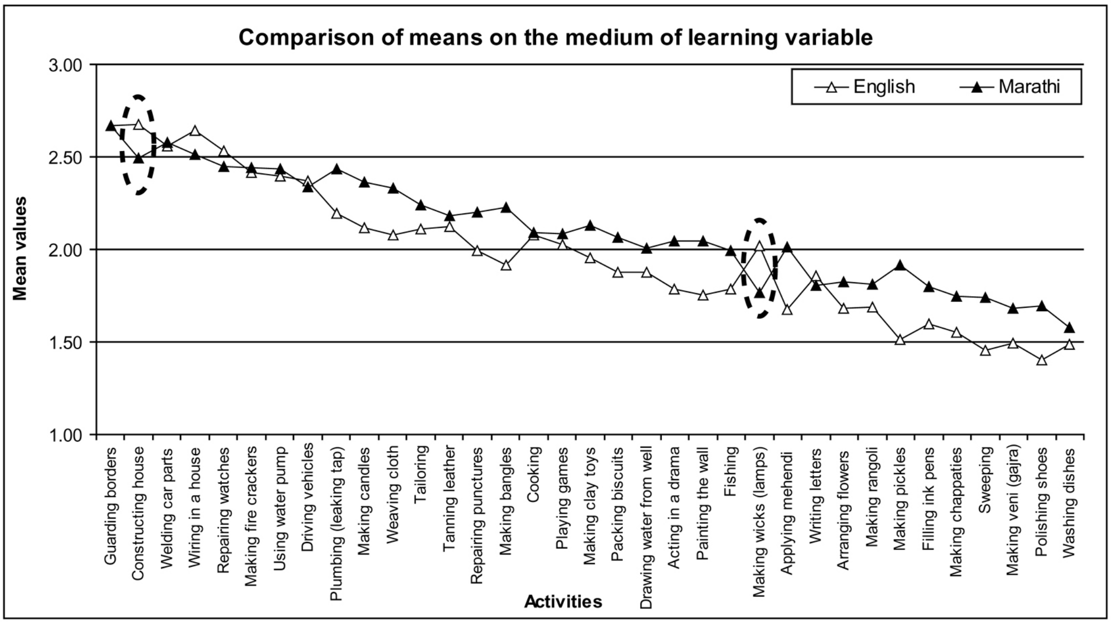


Fig. 3.11: Mean values for the 35 activities on the medium of learning variable.

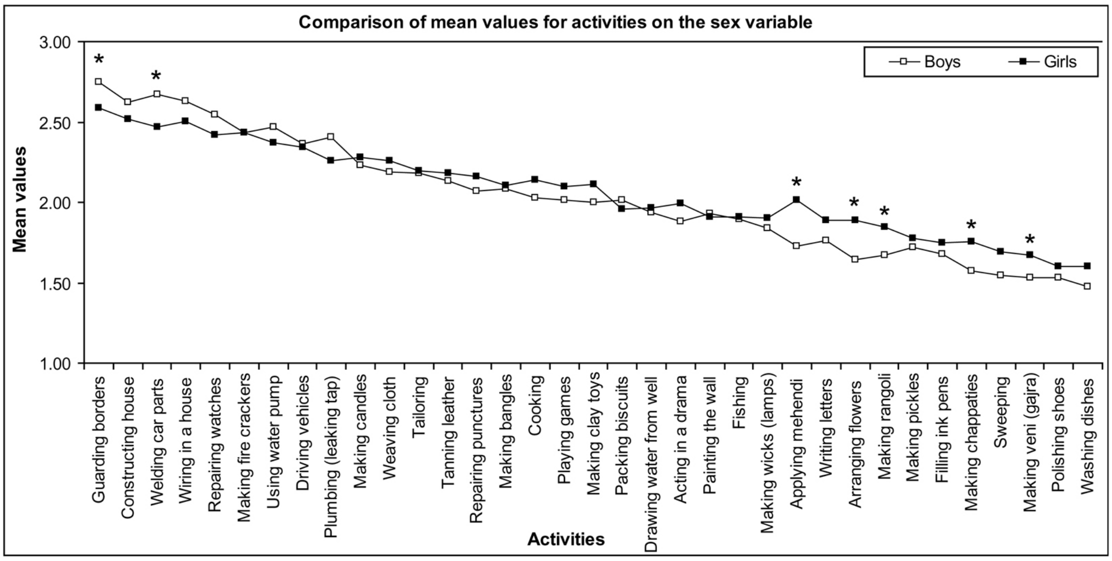


Fig. 3.12: Mean values for the 35 activities rated by girls and boys.

3.7.4 Technology as knowledge

Career choices that students make or the occupations they relate to technological knowledge are important pivots for understanding students' attitudes towards technology. The world of work demands knowledge and skills in order to deliver in a chosen occupation. Do students see technological knowledge as an important requisite to performance in the given occupations? Are there preferences for suitability of careers by boys and girls? These questions will get addressed under this theme.

- On a list of 20 occupations, students had to choose between the *yes*, *unsure* or *no* options to indicate whether they think prior technological knowledge would help one to perform better in each of the occupations listed. Response to each item was numerically coded: tick on *yes* was coded as 1, tick on *unsure* was coded as 2, and tick on *no* was coded as 3. The irrelevant response and no response were coded as 4 and zero, respectively. These were noted for each item, but were not considered for the calculation of mean response.

- A situational question sought student's response in the form of an advise to two friends, a girl and a boy. On a list of 20 occupations, the respondent had to advise whether the career listed was suitable for either a boy, a girl or for both. The question was aimed to unravel the sex-role stereotypes in careers for a girl and a boy.

- Another question aimed to unravel the gender stereotypes associated with routine technological tasks. The question was about a given situation where two friends, Meeta (a girl) and Suresh (a boy) had to finish a set of 10 tasks, before they could go out to play. In the final study, the word "task" was substituted by "job" as it seemed to be better understood among Indian students and also noted during the administration of the pilot survey. However, the semantic distinction between job and task is not so clear in Marathi language. Students had to assign each job either to Meeta or to Suresh. Students' choice of tasks for each would reflect their gender preferences for the given tasks.

Technological knowledge and performance in an occupation

Analysis of the question probed whether students' perceived prior technological knowledge as necessary for improving performance for the list of 20 professions presented here. The means of student responses from the entire sample for the 20 items were arranged in a descending order. For an item, a mean value of 3 indicates that all respondents chose the *no* option for the item, a value of 2 indicates that all chose *unsure* option, and a value of 1 indicates that all chose the *yes* option.

Professions involving manual trades such as carpenter, potter, farmer, mill worker, shopkeeper and vegetable seller emerged as a common factor (Factor 1) explaining the largest variance in the sample. In the Indian context, these professions are also the ones considered as pursued by the academically low performing individuals.

Urban and rural settings

Dancer, Potter, Carpenter and Vegetable seller were occupations seen as not needing technological knowledge by both urban as well as the rural sample. A significantly greater number of urban than rural students believed that computer engineer and doctor were the professions requiring prior technological knowledge in order to perform better. Interestingly, teacher was one profession where a significant greater number of rural students felt that technological knowledge may help them perform better. Teacher, as a disseminator of knowledge, in a rural context receives admiration and respect of village folk.

A much larger proportion thought vegetable sellers (43%) needed technological knowledge. This is in contrast to the occupations of dentists, potters and carpenters (about 30%). Perhaps the contextual role of occupation dominates. In urban sections of the Indian society, a vegetable seller is a person who buys vegetables from a wholesale market and sells them in local markets. Whereas in the rural or village context, a farmer usually sells the vegetables that are produced in her/his farm for sustenance.

Medium and sex variables

Unlike the setting variable, there were less differences by medium and sex of students. Occupation of a carpenter was the only one where difference could be attributed to the medium variable. No difference on items could be solely attributed to the difference in perception of boys and girls for this question.

Technology and occupations

Over the years, with the advent of new technologies, occupational practices have undergone a sea change. One of the most evident shifts have been the move from an agrarian society to a market-oriented industrial society. Within these shifting frames, the social roles of individuals and communities have also changed. Social roles often get associated with certain kinds of occupations and people. These perceptions run deep and strong in the society, so much so that they get reflected as stereotypes, where a particular role is predominantly identified with a particular trait of individual. One such association is the perception of a particular career as suitable for boys or girls.

A question was specifically designed to elicit sex-role stereotypes through the career choices that students suggest. The question had a hypothetical situation where a girl and a boy approach the respondent (student) for seeking advice on suitability of occupations as potential careers. For each of 20 occupations given, students had to mark whether a given occupation was more suitable for the girl, the boy or both.

Among the given 20 occupations, almost an equal proportion of boys and girls saw 8 occupations suitable for both a boy and a girl. Doctor, Teacher, TV news reporter, Artist and scientist were among the top 5 occupations recommended for both, a boy and a girl (see Figure 3.13). This finding concurs with the finding from an earlier study done with first generation learners which revealed that medicine and teaching were careers chosen by both sexes (Chunawala 1987).

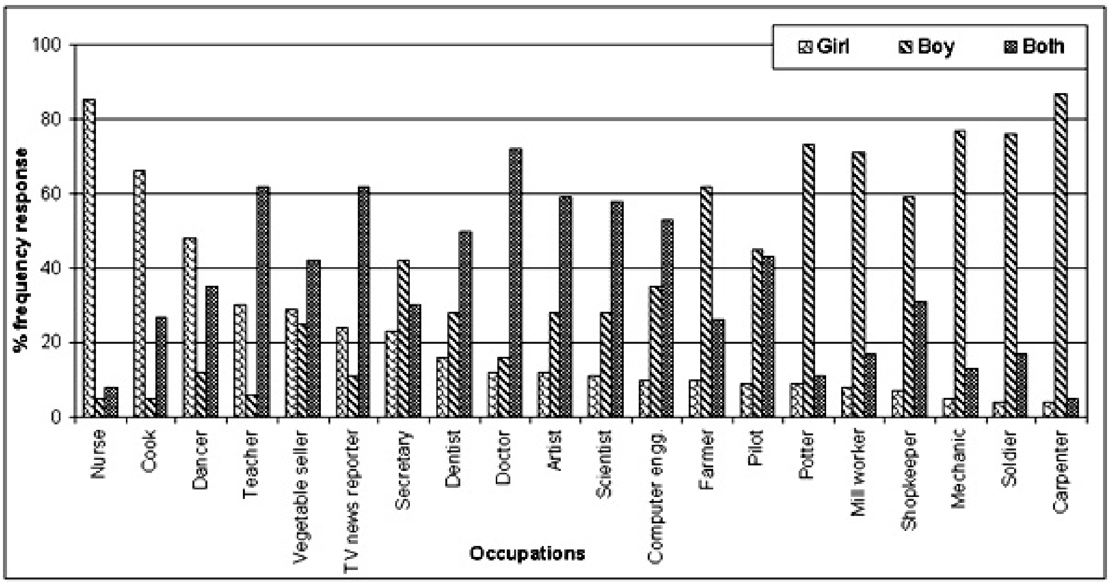


Fig. 3.13: Occupations advised for a boy and a girl.

Nurse, cook and dancer were occupations advised exclusively for the girl by a large majority of both girl and boy sample and reflect the traditional sex-role stereotypes prevalent in society.

Urban and rural settings

The urban students perceive more number of occupations as suitable for both as compared to the rural students. The urban sample is a mix of urban Marathi and urban English sample and subtle play of influences may become clearer in analysis with focus on the other two variables, medium and sex.

Three occupations which were rated by about two third of the sample (>70%) as suitable exclusive for a boy and had no significant differences between the urban and the rural sample. These were: mill worker, potter, and carpenter. These occupations were considered by both urban and rural samples as suitable exclusively for a boy.

English and Marathi medium

Significant differences were noted for the occupation of a teacher and a secretary where rural students rated the occupation as suitable for both while the majority of urban students perceived the activity as suitable for a girl. A significant difference between the English and Marathi sample was noted for the occupation of a vegetable seller and a cook. The Marathi sample perceived vegetable seller as an occupation suitable for both whereas the English sample thought it to be suitable for a boy. A significantly greater proportion of English sample considered cook to be suitable for both, boy and girl.

Boys and girls

On most items, boys and girls had similar perceptions. Vegetable seller was perceived by a significantly higher number of girl sample as an occupation suitable for both. The frequency analysis of responses revealed that the occupations of a Nurse (B: 86%; G: 83%) and a Cook (B: 62%; G: 69%) had a similar proportion of boys and girls perceiving it as exclusively suitable for the girl. Dancer (B: 42%; G: 53%) was also rated by a majority of boys and girls in the sample as suitable for a girl, more by the girls than by the boys and the difference was found to be statistically significant (χ^2=11.170,df=2,p=0.004).

Technology and jobs

Students' spontaneous assignment of 10 everyday tasks to Meeta (a girl) and Suresh (a boy) was studied. The nature of tasks assigned to a girl and a boy in a situation where time was a constraint helped uncover the sex-role stereotypes among students for everyday activities that involve technology.

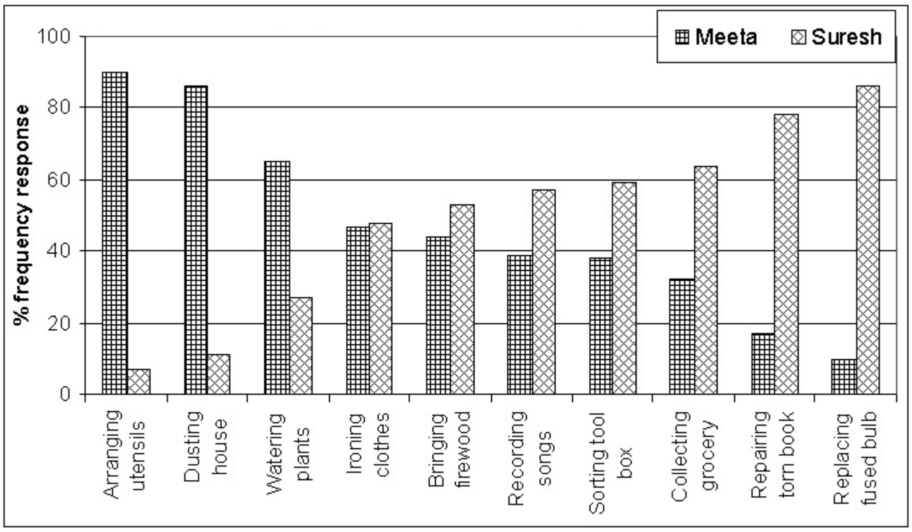


Fig. 3.14: Jobs assigned to a girl (Meeta) and a boy (Suresh).

The spontaneous assignment of jobs for a girl (Meeta) and a boy (Suresh) showed interesting trend as can be observed in Figure 3.14. The largest proportion of students in all sample types assigned the indoor tasks of arranging utensils on a shelf (84-93%), dusting the house (84-88%) and watering the plants (58-73%) to Meeta (girl). Electricity related work, tools and repairs and outdoor duties were tasks assigned to Suresh (boy) by a large proportions of student sample: repairing a fused bulb (75-91%) or a torn book (77-80%), and collecting grocery from a store (58-70%).

Settings, medium and sex variables

The rural sample assigned the job of bringing the firewood (66%) and sorting the tool box (48%) to Meeta. The urban sample assigned these jobs to Suresh. The Marathi samples assigned the task of bringing the firewood to Meeta, while the English sample assigned her the task of ironing clothes. Among the rural and the Marathi sample types, opinion seems to be divided on the task of sorting the toolbox: similar proportions of students assigned it to Meeta (rural 48%, Marathi 45%) and

Suresh (rural 46%, Marathi 50%). This particular job required *working with tools* - a task stereotypically considered masculine, but at the same time required *sorting* - a task stereotyped as feminine. The inherent nature of the job and the stereotype associated with it might have caused the sample to have a divided opinion. Although the girl sample was divided on opinion of whether recording songs on a cassette be done by Suresh (47%) or Meeta (47%), more than two-third (67%) of boys sample felt that the job should be done by Meeta. Traditional sex-role stereotypes prevail even in the spontaneous assignment of a set of tasks to a girl and a boy. These stereotypes are deep rooted and need to the challenged by encouraging practices that can counter such ideas. D&T units could involve activities which encourage participation of both girls and boys on similar activities/jobs.

3.7.5 Technology as volition

According to Mitcham's characterisation of technology, volition implies understanding the consequences of technology. These get manifested in the qualities that students attribute to technology, the goals associated with technology, both at the individual and societal levels and the perceived consequences of technology. Students' reactions to situations of technological change also gave insights into their approach to novel technologies. Nature of questions used for probing this aspect of technology are briefly summarised below:

1. Students had to express their general feeling about technology by marking *yes* or *no* against each of the 10 qualities of technology listed. The items list was a mix of five pairs of opposing qualities: dangerous/safe, useful/useless, unimportant/important, interesting/boring and easy/difficult. The question was intended to gain a firm idea of students' general perception about technology from an affect point of view.

2. Students had to respond to each of the 15 statements on the effects of technology and indicate by a tick mark whether they *agree*, *disagree* or *are unsure* about the statement. Just as in the case of qualities, a positive and a negative counterpart of the statement were included in the list of statements. This helped us probe students' notion of technology as well as validate their responses. The

statements about the consequences of technology were those garnered through literature and that emerged from their portrayal of *image of technology* in our earlier exploratory study among Indian students. The question had an equal mix of positive (08) and negative (07) statements about the effects of technology. This question by its design goes beyond the affect and explores the cognitive component of students' attitudes towards technology.

3. Actions are guided by purposes. In this question students were probed on the extent to which certain goals needed technology. Students had to respond whether technology was *not needed*, *partly needed* or *very much needed* for the goals listed such as making a country powerful, to bring about peace in the world, etc.

4. Students' reactions to specific situations of technological change were probed. These included situations which encouraged a response in framed situations which were personal and social.

Qualities of technology

The first question on the qualities of technology revealed that all the positive qualities were related to technology. This is perhaps the most undisputed finding reported from the multitude of studies on students' attitudes towards technology conducted in different cultural contexts (Corread 2001, de Klerk Wolters 1989, Fleming 1987). Interestingly, all samples had a larger proportion of students saying *yes* to a positive quality than saying *no* to a corresponding negative quality. For example, 93% of urban sample said technology was useful, while 82% felt it was not useless.

The largest proportion of sample marked *yes* for the positive quality and *no* for the corresponding negative quality (e.g. English: useful 98% *yes*, useless 96% *no*). The same trend was noted for other values such as, important, interesting and safe. The response on technology as "difficult" lacked consensus.

English and Marathi medium

Opinion among the English sample seems to be divided for *yes* and *no* response for 2 qualities, namely; dangerous and easy. Almost equal proportions felt that technology is dangerous (*Yes*: 46%, *No*: 53%) and easy (*Yes*: 48%, *No*: 51%). Interestingly, the large majority of English sample agreed with a *Yes* to the corresponding qualities of technology being safe (61%) and difficult (60%). Perhaps, the mixed feeling comes from a cluster drawn from a school run by an atomic energy establishment of Government of India. Students' proximity to the nuclear power reactor and they being aware of the consequences of a nuclear disaster through media and newspapers, and also being aware of stringent arrangements of safety as a priority concern gets reflected through their responses.

Boys and Girls

The differences between boys and girls on all qualities were found to be not significant. Both boys and girls agreed on the positive qualities of technology: a majority ($\gg$ 85%) of boys and girls saw technology as useful, important and interesting. The only exception was technology seen as 'difficult' by nearly half the boys (51%) and girls (49%).

Technology and consequences

Overall, a majority of students among all the samples, agreed to the positive statements about technology: it gets work done faster, helps countries progress, increases comfort, helps wealth creation, removes poverty, is not likely to make country dependent on others, and does not make the poor poorer. This is consonant with the findings in the question on qualities attributed to technology.

Three statements relating to speed, comfort and national interest - it gets work done faster, it increases comfort and helps a country progress - got the highest proportion (58-93%) of agreements from the sample. This positive view is quite plausible since school books and media often highlight the positive implications of science and technology. This image of technology is a reflection of the glorified image of science and technology and the enormous encouragement given to scientific institutions and industries since the Nehruvian era, post independence.

A large majority of students agreed with the statement that *technology brings people together*. This is understandable when one takes into account the wide scale developments in transport and communication technologies that have affected the mobility of people across places. Besides, advertisements in the media and everyday experiences have propagated the advantages of the developments in communication and transport networks. In fact, in our exploratory study using posters as means to probe students' ideas, we found that the predominant objects portrayed were communication and transport devices. Students endorsed the positive effects of technology and disagreed with the negative statements on the effects of technology.

Urban and rural settings

When the statements about technology were negative, student responses were divided between *agree*, *unsure* and *disagree*. For example, about a third of the rural sample were unsure if technology leads to unemployment (37%), causes loss of values (35%), has destroyed crafts (33%), makes the rich richer and poor poorer (32%). A similar proportion (around 30-35%) agreed with these statements as well.

The differences between the urban and rural sample was found to be significant on three statements. The rural sample more than the urban disagreed on the statement that technology leads to pollution ($t(620)=-2.842, p<0.01$). Thus, the urban sample seemed to be concerned about the effects of technology on environment. The urban sample more than the rural sample disagreed that technology makes country depend on others ($t(619)=6.640, p<0.01$) and makes the rich richer and the poor poorer ($t(613)=3.806, p<0.01$).

English and Marathi settings

A significant number of English medium students disagreed with the Marathi students that technology causes loss of values ($t(616)=-4.572, p<0.01$) and that it destroys the crafts ($t(608)=-4.591, p<0.01$). The English sample seems to be more positive on all above aspects except on removing poverty.

Boys and girls

Both boys and girls sample followed a similar trend of responses. However, girls seemed to be more concerned about technology leading to pollution, increases wealth and gets work done faster. Boys more than girls were worried about the compromise on self-reliance because of technologies. A significant number of boys felt that technology makes our country depend on others.

Perceived goals of technology

How do students perceive the changing situations and how do they relate themselves with the technological change in specific situations? A question probed students on the extent to which they felt the technology is needed to achieve the given goals: *Not needed*, *Partly needed* or *Very much needed*. The list contained six items covering a broad spectrum of goals: to make a country powerful, to gain knowledge of the past, to do a job faster, to bring about peace in the world, to provide food and water for all and to save the wild animals and forests. Students had to be indicate their response by a tick mark whether they felt technology was *not needed*, *partly needed* or *very much needed*.

Unanimous opinion emerged among students from all sample types voting for technology *not needed* for gaining knowledge of the past. The order of priority of the goals is suggested by the percentage of students who felt that technology is *very much needed* to achieve a particular goal (refer Figure 3.15).

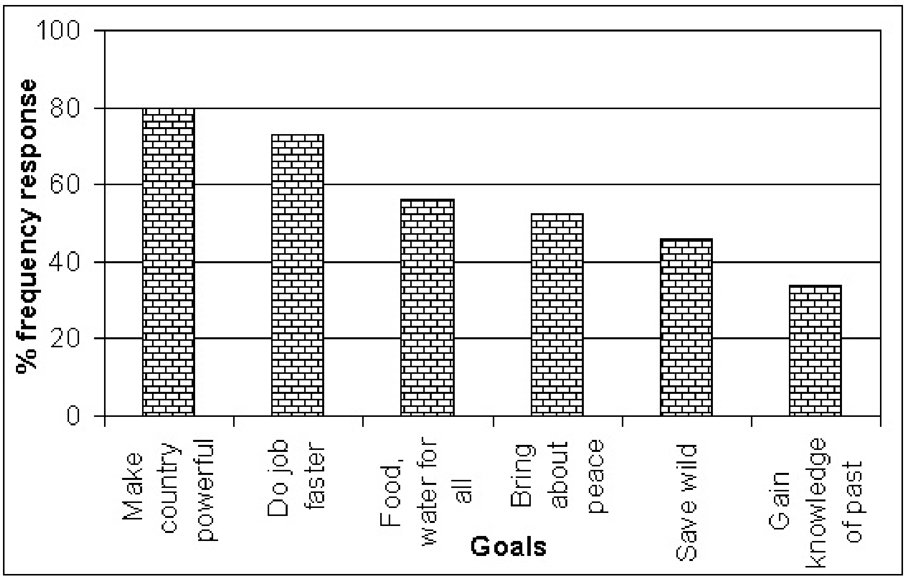


Fig. 3.15: Students' responses as technology "very much needed" for achieving the given goals.

Differences on the setting and medium variables

Difference in perception by the urban and rural sample was noted for the goals of providing food and water to all and bringing about peace in the world. The rural sample perceived these goals to be needing technology very much. Thus, rural sample more than the urban appreciated utility of technology for the broader goals of satisfying basic human needs. Besides these two goals, the Marathi medium students also considered the role of technology to save the wild animals and forest (see Table 3.12).

Boys and girls

It was interesting to note that a significantly higher proportion of girl students among the sample felt that technology helps gain knowledge of the past than the boys. This was the only goal on which significant difference was noted for the gender variable. Girls value the role of technology on these counts much more than the boys.

Students' reflections about technologies

Technologies influence us in every domain of human activity, right from the routine engagements to decisions made at a national or a global level. Students' ideas were gathered on some general and some situational questions. School being the context of everyday activity, students were asked to list the subjects that they thought related to technology. The question being an open-ended one had response with a combination of subjects. These combinations were analysed. Students considered Sciences (Physics, Chemistry, Zoology, etc), Social Sciences (History) and Computer and Mathematics as the school subjects related to technology. Students listing which often had more than one discipline is an indication of their appreciation of technology, an association of activities reflected through several domains of study.

Technology in school subjects

Another multiple choice, multiple answer question aimed at probing their interests in school disciplines required students to indicate through a tick mark the subjects that they would prefer to opt in school. These were a list of 10 subjects, popularly labelled as *vocational and technical* and included: Needle work, carpentry, kite making, book binding, electronics, gardening, cooking, drawing, computers and music and dance. Though the question had options, several combinations were possible and hence resulted in a distributed set of combinations. Only 5% of the total sample preferred all 10 subjects, the rest were combinations of different subjects indicating that students were discriminating their preferences among the subjects listed. However, a general

Table 3.12: Extent of technology needed to achieve listed goals

Goals	Settings				Medium				Gender			
	Type	N (mean)	t	p	Type	N (mean)	t	p	Type	N (mean)	t	p
To make a country powerful	Urban	485 (2.80)	1.61	0.11	Marathi	379 (2.74)	-2.59	0.01*	Boys	314 (2.80)	1.31	0.19
	Rural	149 (2.71)			English	255 (2.84)			Girls	320 (2.75)		
To gain knowledge of the past	Urban	481 (2.20)	0.14	0.89	Marathi	373 (2.21)	0.94	0.35	Boys	313 (2.12)	-2.88	0.01*
	Rural	145 (2.19)			English	253 (2.16)			Girls	313 (2.27)		
To do a job faster	Urban	482 (2.71)	1.62	0.10	Marathi	372 (2.68)	-0.56	0.58	Boys	313 (2.71)	0.96	0.34
	Rural	145 (2.62)			English	255 (2.71)			Girls	314 (2.67)		
To bring about peace in the world	Urban	482 (2.28)	-2.86	0.01*	Marathi	374 (2.44)	4.59	0.01*	Boys	310 (2.26)	-1.93	0.05
	Rural	146 (2.48)			English	254 (2.15)			Girls	318 (2.38)		
To provide food and water for all	Urban	481 (2.36)	-3.10	0.01*	Marathi	374 (2.54)	5.31	0.01*	Boys	310 (2.43)	0.83	0.41
	Rural	149 (2.57)			English	253 (2.21)			Girls	317 (2.38)		
To save the wild animals and forest	Urban	484 (2.28)	-0.08	0.94	Marathi	372 (2.36)	2.99	0.01*	Boys	312 (2.32)	1.24	0.21
	Rural	143 (2.29)			English	255 (2.17)			Girls	315 (2.24)		

Note: * = significant

pattern can be deduced from the responses. The most commonly preferred subjects were electronics, computers and drawings.

What could be the possible benefits of learning technology? Students' responses were sought on a question that stated four perceived reasons for learning technology: acquire knowledge, acquire skills, gain the means to do what we want (empower ourselves) or to get a job easily. They were asked to indicate with a tick mark, what they felt was the goal of learning technology. About a third (29%) chose all options. But the response of others was a combination of options. About a fifth of the sample (18%), who chose a combination where the last option of a job was not an important part, seem to emphasize the intrinsic value of learning technology. This was followed by 14% choosing a combination which did not include gain skills. The variety in combination of responses suggests the different emphasis of students for learning technology: majority opted for all options, while others emphasized the intrinsic value and some the aspect of knowledge more than others.

Users of technology

At a general level, on being asked about who uses technology, nearly half the English sample and 30% of the rural sample felt that people in cities use technology. Nearly half the proportion of urban Marathi sample felt that both people in cities and villages use technology. The options available to students were a bit tricky and hence received a distributed response for cities and both. Technology used by *People in villages* was a possibility ruled out by students in all samples. Cities as harbours for technology is an image reminiscent of industrial boom where many rural migrated to cities in search of jobs and better wages. Industry-based technologies with organised labour, mass production and economic returns eclipse the role and influence of rural technologies.

The question had a sub-part with a set of 4 statements where students had to indicate whether they *agree* or *disagree* with the listed statements. More than half of the urban and the rural sample disagreed that all people get an equal chance to use technology. This means that half the urban and rural samples agreed that people do get an equal opportunity. Those who felt that technology is not egalitarian had to suggest reasons from the same. Poverty as a reason had a consensus of over two-thirds of the sample. The other reasons were not having the requisite knowledge of use, having a closed attitude and no desire to know about new things. Though, not very concrete in terms of its output, this question provoked students to think about technology and opportunities of access and use.

Ability, advancement and technology

Concept of technology can be understood not only in terms of human-made artefacts, but also the felt requisites of a technologically able person. A question required students to indicate on a list of 4 options the qualities that are necessary for a human to be technologically able. The 4 critical features of thinking, planning, making and designing were items listed. On each item, student marked her/his agreement or disagreement. The responses are presented in Figure 3.16. Thinking was perceived to be important by most students and designing the least.

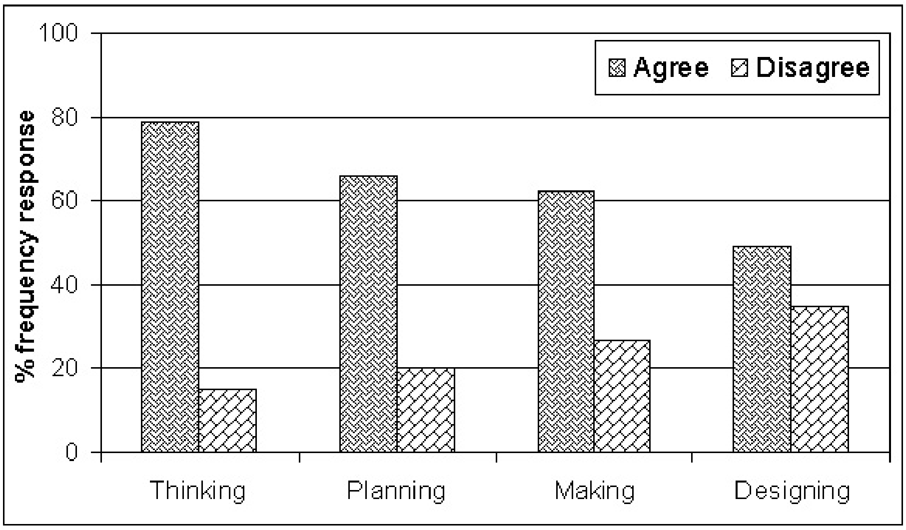


Fig. 3.16: Percentage frequency of responses for items considered important for being technologically able.

Citizens of a nation are emotionally tied with values and sense of pride and respect. The perception of progress and advancement is very often discussed with technology. What one envisions for a progressive nation also reflects the personal feelings and attitudes of people. A question probed what students felt was necessary for a nation to be considered technologically advanced. The question requested students to respond on *agree*, *disagree* response structure, to a set of 5 items: nuclear power plants, modern agricultural plants, modern agricultural tools, weapons, food for all and modern industries. The frequencies of responses were calculated for the three variables and were then ranked as in Table 3.13.

Table 3.13: Students' ideas about technologically advanced nation.

	Total		**Settings**				**Medium**				**Gender**			
			Urban		*Rural*		*Marathi*		*English*		*Boys*		*Girls*	
	%	R	%	R	%	R	%	R	%	R	%	R	%	R
Nuclear power plants	78	2	84	2	57	4	74	3	83	3	82	2	73	2
Modern agri. tools	75	3	78	3	66	2	68	4	86	2	77	3	73	2
Weapons	64	5	67	5	55	5	66	5	75	4	68	5	60	3
Food for all	71	4	70	4	75	1	75	2	65	5	69	4	73	2
Modern industries	83	1	89	1	64	3	77	1	90	1	85	1	80	1

Note: R = Rank

The rural sample was exceptional in prioritizing *food for all* as the top most need of a technologically advanced nation, followed by modern agricultural tools and then modern industries. The rural sample, who often have to live on minimal food, considered food to be the most crucial. All other sample types had the highest proportion of students ($\gg$ 80%) agreeing strongly on the possession of modern industries. This again is a reflection of the urban environment where industries are the considered to be the hub of work activities and are sources of income generation. The sustenance pattern and economies influence students' ideas of what a technologically advanced nation should possess. Thus, students' considerations of technological advancements are shaped by their local contexts and immediate dependencies: industries and power supply for urban settings and food and agriculture for the rural settings.

Students' reactions to novel technologies

In the past few decades there has been an usher of new technologies at a much greater speed than ever in the history of humankind (Toffler 1970, Lawson 2006). How one responds to a technological change also reflects the attitude towards technology. This was probed through some questions that were situated in the urban and rural contexts. One question considered a situation where a new computer is brought to the students' school and 5 most likely reactions were listed. Students had to place themselves in such a situation and indicate whether they would have reacted in a similar way by opting either a *yes* or a *no* response. Thus, this question probed student on a personal reaction to a novel technology. Frequency of students' responses as *agree* was calculated and a rank was ascribed for each option. The frequencies and ranks for each option for the 3 variables are summarised in Table 3.14. The response trends suggests that majority of students preferred a demonstration when a new computer was introduced. This was followed high proportion of students indicating their desire to be the first person to use it. Students never showed an aversion to a new technology.

Table 3.14: Students' response to a situational question on a newly introduced computer.

	Total		**Settings**				**Medium**				**Gender**			
			Urban		*Rural*		*Marathi*		*English*		*Boys*		*Girls*	
	%	R	%	R	%	R	%	R	%	R	%	R	%	R
First to use it	69	2	68	2	72	1	64	2	75	1	69	1	69	2
Teacher shows	72	1	75	1	64	2	73	1	71	2	69	1	75	1
Let others use it	31	3	28	3	41	4	37	3	23	3	33	2	30	3
Not interested	28	4	22	4	45	3	33	4	20	4	29	3	17	4
Afraid of using	15	5	12	5	27	5	18	5	11	5	17	4	14	5

Note: R = Rank

A similar question, situated in the rural context, concerned the knowledge of high yielding varieties (HYVs) of seeds. The situation required students to advise on the use of the high yielding seeds in the friend's field. The question had a rural context and an emotional link (friend's father). Students had to indicate by a tick mark whether the *agree* or *disagree* with the statements listed. The frequency of student responses on each statement for the entire sample and the 3 variables was calculated. The frequencies marked as *agree* were then ranked, the highest frequency was ranked 1. It was interesting to note that the trend of students' response on the 3 variables was almost the same (see Table 3.15). Testing the seeds and using them in the fields were the options which reflected unanimous choice of students. The common choice by the large majority of students reflected their positive and confident attitude towards approaching a new technology. Distrusting products or waiting for others were options that had low ranks. Thus, pointing to the confident embrace of new technology albeit with experiments, in order to be watchful of consequences. In both the cases, that of a computer and advise to a farmer, students seemed to be a curious mix of innovation (risk-taking) and caution. They wanted to explore new possibilities but at the same time were cautious of potential consequences.

Yet another situational question probed students on a societal issue, which would have

Table 3.15: Students' response to a situational question on high yielding seeds.

	Total		**Settings**				**Medium**				**Gender**			
			Urban		*Rural*		*Marathi*		*English*		*Boys*		*Girls*	
	%	R	%	R	%	R	%	R	%	R	%	R	%	R
Use them in fields	53	2	52	2	56	2	40	2	73	2	56	2	50	2
Let others use it	28	4	27	4	31	5	28	5	29	4	29	4	27	4
Distrust products	24	5	17	5	47	4	29	4	17	5	27	5	22	5
Test seeds	76	1	82	1	59	1	67	1	89	1	77	1	75	1
Wait to see effect	42	3	40	3	48	3	34	3	55	3	42	3	42	3

Note: R = Rank

consequences for a nation. India had conducted its nuclear tests at Pokharan in 1998. The issue was much in debate and received attention in open discussions and in the media. Taking into account the context, students' reactions to such a technological development was gathered through a situational question. The question had an affect element and students were requested to indicate through choosing either the *agree* or *disagree* option on a list of 8 possible reactions to their country's plans to conduct nuclear tests. The frequency of responses was calculated for the three variables and the total sample and were then ranked. Table 3.16 presents an account of frequency responses and ranks for the three variables studied.

It was interesting to note that $\gg 80\%$ of the students in all sample *agreed* that they would feel proud that their country is powerful. A large proportion of the urban and rural students (68-75%) felt that they would be excited about the developments, but almost an equal range of students felt that they fear that it will harm people and the environment. Such polar attitudes on a situational question give valuable insights into how students think of a novel technology.

However, very few students agreed of being disinterested or registering a protest against the nuclear power plant. It is interesting to note that the feeling of pride dominates and stands as a prime one, followed by excitement and then thinking about the consequences as revealed through the ranks across the three variables. The emotional aspects thus play an important role in students' judgements about a novel technology. The finding draws our attention to the role of emotions in human decision-making, an aspect to be considered and valued while engaging students' in technology units. Further, a determined attitude of students to favour novel technologies, but at the same time be cautious and concerned about its consequences was interesting.

Table 3.16: Students' reactions to their country conducting nuclear tests.

	Total		**Settings**				**Medium**				**Gender**			
			Urban		*Rural*		*Marathi*		*English*		*Boys*		*Girls*	
	%	R	%	R	%	R	%	R	%	R	%	R	%	R
Feel proud	88	1	88	1	89	1	91	1	84	1	89	1	87	1
Fear of arms race	52	5	56	5	41	6	49	5	57	5	57	5	48	5
Effect on environ.	73	3	74	3	72	2	77	3	67	3	69	4	77	2
Be excited	78	2	81	2	68	3	78	2	78	2	82	2	74	3
Worry: expenditure	44	6	44	6	44	5	49	5	38	7	45	6	43	6
Be disinterested	21	8	17	8	34	8	25	7	14	8	23	8	19	8
Active support	69	4	71	4	63	4	72	4	65	4	72	3	65	4
Protest against it	35	7	33	7	39	7	30	6	41	6	40	7	29	7

Note: R = Rank

3.8 Middle school students' ideas about technology: Salient points

The survey study yielded insights into Indian middle school students' perception of and attitude towards technology. Though students did not have technology as a subject in the school, they nevertheless are growing up in more or less of a technoscientific culture (Aikenhead 1988). The study sought to unravel ideas of technology among urban and rural students, with English and Marathi as the medium of learning and the differences in the perceptions of girls and boys in the sample studied. The questionnaire engaged students in thinking of technology in its multiple manifestations.

- Students saw technology as an important component in their lives, in career prospects, and in their future endeavours. They also perceived technology as necessary for nation-building and progress.

- Students were willing to engage in design and making activities, if they were motivated by an appropriate context. The interest of the urban as well as the rural students in opting to make a toy, rather than buying one from the market, demonstrates this.

- Overall, students had a positive image of technology. This was noticed in their aspirations, attributes they associated with technology, goals that technology satisfied and consequences of technology for individuals and society. A large number of students felt that technology plays an important role in their lives: in fulfilling their future plans, in their interests and aspirations. Most students agreed about the beneficial aspects of technology. This finding is in line with findings of numerous PATT studies in contexts where technology has been a school subject (de Vries 2005).

- Students considered power-driven (petroleum fuel, electricity or electronic) artefacts as involving high technology. Sports and musical instruments were rated as involving no or low technology. The large number of objects, activities rated as involving *low* technology suggest a distributed perception of technology for that item rather than a firm acceptance of it as involving low or no technology. Extent of technology seemed to be influenced by multiple dimensions such as, the nature (simple/complex, mechanical/non-mechanical, electrical/non-electrical) and purpose (domestic/technical) of objects involved apart from the aspect of students' exposure and context of use.

- Judgements of the extent of technology in activities seemed to be influenced by objects involved and the physical context associated with the activities. Outdoor activities involving technical objects were considered as involving high technology. On the other hand, non-electric domestic objects were rated by students as not involving any technology.

- Temporal aspect also seemed to play an important role in judging an object as technological as seen by the large agreement on objects such as computers, television and telephone. Introduction of these objects have brought profound change in the lifestyles of Indian people. Contrasts on student response to an ancient, manual and an equivalent modern mechanical object brought out the technological aspect of modernity. This is understandable because the "modern" in the sense of historical development of technologies connotes the post-industrial revolution period, wherein mechanisation became a hallmark of progress. No wonder, technical devices operating on power were rated by a large majority of students as involving *high technology*.

- Differences among the urban and rural samples were the largest of any variable, suggesting that the perceptions of technology were greatly influenced by exposure to and experiences of technologies in the local context.

- Occupations advised to a friend, role of prior technological knowledge in professional performance and spontaneous distribution of tasks to be done, all exhibit sex-role biases in responses. Thus stereotypes in the role of gender in doing technology emerged as a crucial factor.

- Students' considerations of technological advancements are shaped by their local contexts and immediate dependencies, such as industries and power supply for the urban setting, and food for the rural settings.

- Situational questions of technological change involving introduction of novel technologies at the level of individual (computer), influence of a common basic social need (high yielding seeds) and at a national level (nation going for nuclear tests) revealed that students had a curious mix of attitudes: being somewhat adventurous and also cautious in their approach to a new technology.

- Impact of technologies on environment emerged as important concerns perceived by students in newly introduced technologies.

- Technology seemed to have a confused identity. At least three such tunnelled perceptions of technology were evident: (1) Technology as science: from their brief descriptions of future plans, the high ratings accorded to objects related to science (such as laboratory apparatus) and the associations they make on hearing and talking about technology. (2) Technology as computers: Computer as an object, computer engineer as a profession, computer in school subject all had consensus in students' responses that computer involved *high technology.* Other studies have also reported that people equate technology with computers and the internet (Rose and Dugger Jr. 2002, Rose, Gallup, Dugger Jr. and Starkweather 2004). Speed and efficiency were qualities associated by a consensually large set of sample types. Perhaps, computers may be seen as an effective tool aiding such a process. (3) Technology as the technical: Objects, activities and professions that involved technical aspects either in terms of knowledge requisites, their use, or their performance were considered as involving high technology. These three perceptions of technology have also been found to be dominant in other studies reported in literature on students' attitudes. There is an urgent need to produce counter instances which challenge these narrow and limited perceptions.

Chapter 4

Development and trials of Design and Technology (D&T) education units

This chapter examines the issues and concerns that were involved in the development of the three D&T units. Ideas for development of the D&T units were drawn from the literature and insights from our survey study, and were built on the learnings from the field trials in different settings. Literature that guided the development has been discussed here under six major aspects. This chapter begins with a brief introduction to these aspects and present the objectives of the development and trials of the D&T education units. This is followed by details of methodology and sample for the trials. The chapter concludes with a summary on the learnings from the development and trials of D&T units.

4.1 Introduction

Several aspects need to be considered while developing technology as a subject in general education. These are listed and discussed below.

- Perceptions of technology among students and teachers
- Content of technology education

- Cognition and technology education
- Teaching design and technology in schools: Classroom interactions
- Classroom resources
- Evaluation, assessment and teacher preparation

4.1.1 Perceptions of technology among students and teachers

Prior understanding that students and teachers bring to the classroom shapes learning. Survey studies form a means of gathering prior conceptions about a particular theme. In our case, the survey served as a precursor to the development of our D&T units. Among other findings, the significant differences noted among the sample types clearly demonstrated their differential exposure and access to technologies. Engaging students in activities involving a range of artefacts and systems might help them go beyond the narrow perception of technology and encourage them to appreciate the aspects of technologies in everyday artefacts, processes and systems.

4.1.2 Content of technology education

Technology education draws from the knowledge and practices from different disciplines like history and philosophy of technology, the natural sciences, the social and behavioral sciences, art, design and education. The foundational aspects, like the nature of technology portrayed in the classroom including the relation of technology to other disciplines, may be drawn from an understanding of the history and philosophy of technology. Technology educators can use instances from the history of technology to arouse students' interest and as a context for classroom activities (Solomon 1996). Philosophy of technology can be used to understand the diverse meanings of technology and facilitate meaning making in the classroom.

Content of technology education relates to the kinds of knowledge, skills and processes used in the conceptualising and making of artefacts and systems as part of teaching technology. The content may include the historical and current contexts relevant to the artefact, as well as aesthetic, socio-economic and ethical values. As is true for all teaching-learning situations, the content needs to be cognitively and socio-culturally appropriate to the students and their settings. Thus, insights about choice and organisation of the content of technology education derive from cognitive science.

4.1.3 Cognition and technology education

Educational philosophers and social reformers among several others have argued for technology as part of general education. Arguments in favour of technology education seem to be grounded in four kinds of reasons: attitudinal, philosophical or epistemological, cognitive and behavioural. Attitudinal aspects include concerns related to broadening attitudes towards technology, and those that contribute to forming a wider perception of technology. Philosophical or epistemological aspects relate to including technological literacy in general education, the benefits of an integrated approach to learning, which transcends disciplinary boundaries, and approaches that advocate the vitality of including social aspects into teaching technology. Cognitive reasons pertain to nurturing specific domain of knowledge, skills and practices embedded in authentic technological situations. Behavioural reasons include aspects of skill and training leading to the efficient use of materials, tools and other resources. These also include making judgements based on aesthetic, technical and social considerations.

Among several reasons put forward for the inclusion of technology education in general education, some are related to cognitive development of students, while others address affective and socio-cultural aspects. The priority given by educators to one or more of the reasons help structure the content and pedagogy of technology education. Some technological engagements encourage the use of visuo-spatial skills of imagination, representation and manipulation while others emphasize psycho-motor skills in tools and resource use. Technology education can be structured to encourage a balance of the mental (cognitive) and the manual (motor) activities and to provide opportunities for students to integrate the knowledge and skills learned in isolation under specialized school subjects.

Technology education shapes students' attitude toward the technological world (Senesi 2000). Use of variety of tools and materials, encouraging alternate design ideas, integrating evaluation of artefacts and processes help widen the view of technology from that of being merely products, to technology as processes and systems as well. Activities with increasing complexity help students' progress in learning technology, including skills (the 'know-how') and knowledge (the 'know about'), which can then be noted within a unit as well as across a sequenced set of units.

4.1.4 Teaching design and technology in schools: Classroom interactions

The content and structure of technology education, classroom interactions and sequence of learning units depends on the goals of teaching technology in schools. Currently, vocational and technical education at the secondary level in Indian schools is perceived as being suitable for low academic performers and 'drop-outs'. It is seen as a stream, which trains pupils in trade skills - crafts like carpentry, technical and industrial skills, thus making the student activities largely prescriptive. Most school activities are individual-centered and there is no scope for collaboration or team-work. If technology education is to be a valued aspect of school education and meaningful in later life, technology education units must encourage students to work in teams and in problem-solving situations that allow for a variety of solutions. Keeping these aims in mind, we have developed a model for technology education suitable for the Indian schools.

4.1.5 Classroom resources

School learning in any domain depends on the structure of classroom interactions and use of educational aids and participation level of students. Some of these choices are influenced by students' contexts and prior exposure to material resources. For instance, internet and computers were not accessible to students in the tribal settings while television and print media in the form of newspapers and school textbooks were accessible to all. The development of technology education units included consideration of students' backgrounds in the choice and structure of activities.

4.1.6 Evaluation, assessment and teacher preparation

Though issues of evaluation, assessment and teacher preparation are very important aspects in the implementation of technology education as part of general education, these have not been the focus of the development and trials discussed here. However, self and peer evaluation of the processes of design and making as well as the final product were integral part of the units and classroom interactions. How the above aspects influenced the development and trials of D&T units will be discussed in the methodology in Section 4.3.

The objectives that guided the process of development and trials of the D&T units will be discussed below.

4.2 Objectives

The principal objective of the study was the development through classroom trials, of D&T units suitable for urban and rural Indian middle school students. The units developed aim to satisfy several criteria listed below.

- Design technology tasks that may appeal to both girls and boys as well as urban and rural students.
- Set the design and technology problem in a context familiar to students and engage them in design problem-solving through a loosely structured sequence of tasks.
- Build student-teacher/researcher interactions, where student groups collaborate within and between groups, and with the teacher/researcher, towards achieving the goals negotiated in class.
- As they envision (design) and make their desired artefact, encourage students to engage in exploration of tools and materials, their properties and functions.
- Design activities within each unit that involve acquiring and using knowledge (of materials and its properties), skills (of estimating, qualitative thinking, commu-

nicating, manipulating and critically evaluating) and values (aesthetic, social, economic, ecological).

- Include visualization and design tasks, planning, active construction and critical appraisal of the processes and the finished products.
- Encourage peer review, critical evaluation and communication among students.
- Provide opportunities for students to explore contexts of technology that convey the idea that technology manifests variously as a product, process or a system.

4.3 Methodology: Designing D&T units

The development and trials of units for technology education among Indian middle school students sought to achieve the objectives listed and were guided by the six aspects briefly discussed in the introduction to this chapter. The units were developed to suit the selected sample of students. Hence, first the background of the sample group is given below. This will be followed by the discussion on the development of units in terms of the six aspects.

4.3.1 Sample

The sample consisted of middle school students, studying in Class 6 (age 11 to 14 years), from three distinct socio-cultural settings: an urban Marathi medium school, an urban English medium school and a rural (tribal) Marathi medium school.

The choice of a sample was crucial and had major implications for the nature of activities built in each unit. Adolescence is a transitionary phase in the development of children (Mahn 2003). Theories of development identify the middle school stage as the phase where many changes occur in the cognitive and physiological domains of students. Writing and drawing, the two major modes of expression have a profound influence during this crucial phase of development. In the developmental stages of drawings, students are observed to move from Symbolic realism (where they tend to represent their image of the world through symbols and concentrate less on depicting reality) to Realism (where they make efforts to represent the objective world close to reality) (Piaget and Inhelder 1995). Thus, they are able to represent real objects in their depictions, a useful quality that helps in design of artefacts. The capacity to express through writing, which also is a reflection of the thought process of a child is fairly well developed. The child at the middle school level is able to reason and present her understanding as coherent and meaningful arguments. Beginning from 11 years of age, children develop the capacity for abstract, scientific thinking and propositional thought (Berk 1997). Students in class 6 (age 11 years) are a group among whom the abilities to engage in formal reasoning, making things explicit and to generate productions that reflect real world objects, ideas and themes develop and hence serve an ideal age group for base investigations. All these abilities are essential for achieving our research goals.

The sample selection was guided by three broad concerns: (a) inclusivity in terms of students from urban and rural settings; (b) trials in a local language (Marathi) besides English; and (c) inclusivity in terms of boys and girls.

Some of the systemic differences between the three settings from which the sample was selected have already been discussed at length in chapter 3, section 3.3.2. The specific aspects relevant to the trials of the technology education units and pertaining to the three schools are summarised in Table 4.1.

Students' willingness to participate in the study, proximity of the school to researchers' institution and the researchers' rapport with the school management also influenced the selection of the school and sample. The field trials with urban students were conducted either after school hours or during school vacation. It was possible to conduct the trials at the Centre as these schools were in the vicinity of the researchers' institution. In all the three socio-cultural settings, permission was sought from the school's Principal to conduct the trials of our units. The researchers requested for about 25 students from Class 6, with an average academic performance, preferably equal number of girls and boys, who would like to volunteer for the trials. In the urban setting, consent was sought from the parents of the students who volunteered. For the rural (tribal) school, permissions were sought from the Project Officer, Tribal Development Project of the Thane district of Maharashtra.

Thus, the selected sample included diverse socio-cultural settings and two different languages of instruction, namely English and Marathi, the language of the State.

Table 4.1: Sample profile

Criteria	**Urban Marathi**	**Urban English**	**Rural Marathi**
Proximity of school to our Centre	About 1/2 km	About 1/2 km	About 65 km.
Type of school	Day school	Day school	Residential (*Ashramshaala*)
School aid and management	Private trust & State Govt.	Govt. Dept.	Tribal Welfare Dept. of the Govt.
Curriculum (Board)	State	Central	State
Divisions per class	2 to 3	3 to 4	1
Teacher:Pupil ratio	1:70	1:40	1:50
Classroom settings	Benches, blackboard, sandstone tiles, natural light	Benches, blackboard, lights, fan, mosaic tile floor, well-lit classes	No benches, part of wall coloured black, unmaintained sandstone tiled floors, low power supply for a few hours, dim-lit classes
Educational aids used	Blackboard, charts, books	Blackboard, charts, OHP/LCD	Blackboard, charts, books
General facilities	Toilets, library, playground, drinking water	Well-maintained toilets, library and playground, drinking water	Dirty toilets for girls and open-spaces for boys, poor library, unmaintained playground, bore-well water for washing clothes and drinking
School provides	Scholarships for select students	Scholarships for the meritorious	Scholarships, uniform, books and monthly amount for personal maintenance
Commuting to school	Public transport - bus, local train, or foot	Personal mode - bicycle, parents vehicle	Nil
Linguistic background	Mostly Marathi	Mixed Indian languages	Dialect of Marathi
Parents educational background	Some schooling – literate	Well educated (usually both parents have a degree)	Mostly Illiterate
Average occupation of parents	Service jobs	Most work in a Govt. research institute	Mostly farm labours or workers in small-scale industries

A conscious effort was made to have a near equal number of boys and girls in the sample. The sample distribution is given in Table 4.2.

Table 4.2: Students participating in the trial of the 3 D&T units

Social setting	**Bag**			**Windmill**			**Puppetry**		
	Girls	Boys	Total	Girls	Boys	Total	Girls	Boys	Total
Urban Marathi	10	10	**20**	09	13	**22**	11	10	**21**
Urban English	10	11	**21**	09	10	**19**	09	11	**20**
Rural Marathi	10	10	**20**	12	12	**24**	14	12	**26**

The trials were conducted between August 2003 and September 2004 while the academic year in all the schools was from June to April. Each technology education unit was carried out in every setting over 15 hours spread across 5 days. The language for researchers' instructions was the same as the medium of instruction in each of the schools.

The urban students were from schools in the vicinity of the researchers' institution and from similar urban settings. Hence, they soon became friendly with the researchers and familiar with their methods. The tribal students however needed a few preliminary sessions for familiarisation and ice-breaking and are referred to in later discussions as the "make-up sessions". For instance, two sessions that included structured activities like playing games with shared rules, categorising leaves, describing the forest and designing a postage stamp preceded the second technology education unit trial. Video cameras and audio tapes were also used during these activities to help students get comfortable with the presence of such equipment.

4.3.2 Development and trials

This research draws ideas of technology education from the theoretical tradition of socio-cultural theory of learning, which acknowledge the fact that knowledge is closely related to the context in which it has been learned and used (McCormick 2006). The fact gets reiterated in the situated view on learning which regard learning as a process of enculturation into a domain through participation in shared activities (Lave and Wenger 1994, Wolff-Michael 1998). Central to these theories are the role of context in learning, creating and sharing meaning through collaborative engagements. Technology is a social endeavour and technologies are shaped and acquire their meanings in the heterogeneity of social interactions (Bijker 1997). These theoretical tenets need to be integrated in the school learning experiences in design and technology education.

Among the several models for teaching technology, the Assessment of Performance Unit (APU) model that advocates the Design-Make-Appraise (DMA) approach for teaching technology to school students from the primary through secondary levels practised in UK (Kimbell et al. 1996) served as an important source of inspiration for our research. The APU model places a pivotal role to the element of design in technology education, a fact which is quintessential to the process of technology (de Vries 1992). The APU model has been modified to suit the research aims as well as to study the collaboration and cognition in classroom interactions through gender and other socio-cultural lenses, like the school setting. Our model is discussed in Section 4.3.7.

The development and trials recognise the value of engaging students in collaborative problem-solving (Hennessy and Murphy 1999), an idea which is integral to the notion of technology stance proposed by Rowell (2004). The technology stance integrates social aspects of technological activities in school learning. According to this view, discourses around design and designed systems, mediated by the use of tools, resources and language, address decisions made by people in using materials and building devices, which have an impact on the way humans live. Trade offs due to constraints, anticipation of possible failure, assessment of risk and human judgements, are all integral to technology practices within an active community like a classroom. D&T education units, which are authentic design problem solving situations, can best integrate these theoretical aspects into rich experience of learning engagements both for students as well as teachers.

Conceptualisation and design of the artefact was integral to each technology education unit. Besides, the development and trials of the units itself followed the process of design. Goals evolved during the development, constraints of the units emerged, and the trials provided the feedback to refine the units. Figure 4.1 encapsulates the process of development through trials. The units developed were tried in one setting and insights gained from the trial in one setting led to modifications before the subsequent trials. Thus, development of units was a continuous process of feedback and modifications.

The process of designing the D&T units as it happened for the three units is reflected

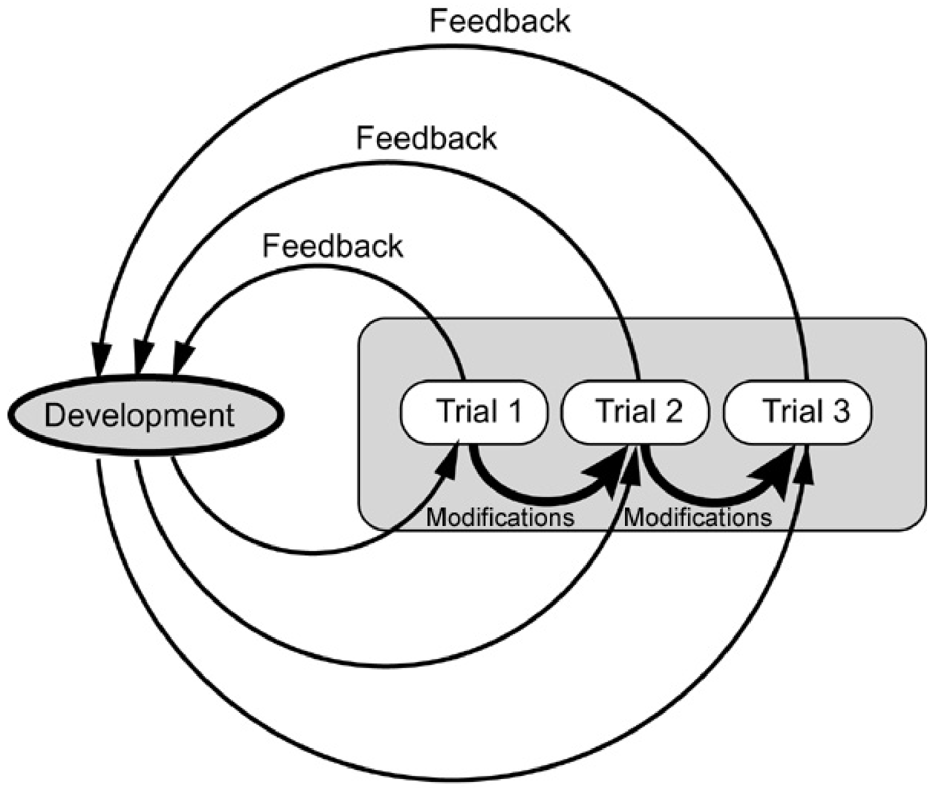


Fig. 4.1: The process of development through trials.

upon below in terms of the six aspects that guided the design. Analytical findings during development and trials as evidenced from the classroom observations and daily logs will be discussed in Chapter 5.

4.3.3 Influence of students' and teachers' perceptions

Literature on attitudinal studies and on perceptions about technology reveal that students as well as lay people associate technology predominantly with objects (products) and rarely with processes (activities) and systems. The findings of a study carried out by us among Indian middle school students reported in Chapter 3 indicated similar response trends. Students tended to perceive static, ancient, indigenous and non-electrical devices or those which do not use fuel, as involving *low technology*. All dynamic, modern, electrical or electronic and fuel-run devices were perceived more often as involving *high technology*. Domestic objects as well as domestic contexts of technological activities were perceived as involving *low technology*. These findings suggest that students indeed have a very narrow perception of technology limited to certain locales, activities which are modern, automated or fuel-run.

Technology related learning experiences of students are known to shape their perceptions of technology (Heywood 1998, Senesi 2000). Exposure to a wide variety of artefacts and contexts of technological activities complemented by engagement with the processes of planning, designing and making artefacts may help broaden students' perceptions of what constitutes *technology*.

The process of developing D&T units for middle school students began with a few brainstorming sessions among researchers leading to generation of a list of possible D&T education units. Several considerations and constraints helped the selection of suitable ideas. Use of a diversity of materials and resources alone could not explore the broader conception of technology as products, processes and systems. Hence, a number of other criteria were applied. Besides, some of the potential units in the list of D&T units evolved during exploration of ideas. Figure 4.2 gives a glimpse of the explorations made by researchers which helped us understand the range of skills and ideas that go into designing an artefact. The units could engage middle school students in differentially complex tasks or may be differentially familiar to students from different ecological and socio-cultural settings. Two major considerations that emerged were complexity and the level of familiarity of the artefact among the sample of students.

Complexity: In the analysis of students' design productions, complexity refers to the number of components and the nature of assembly involved in making the functional artefact.

Familiarity: The meaning of familiarity in our frame of analysis implies artefacts known to students either through frequent access, reading or knowing about from sources and/or by frequent use of the artefact.

The potential ideas were screened. For example, a container to hold a variety of (office) stationery items on a table was not suitable for tribal students, who had little exposure to such office products. A bird feeder, on the other hand was alien to students in Mumbai city. Hence, a few units which were suitable for both the rural and urban contexts and would have activities that appeal to both girls as well as boys offering opportunities for exercising different skills and abilities were chosen.

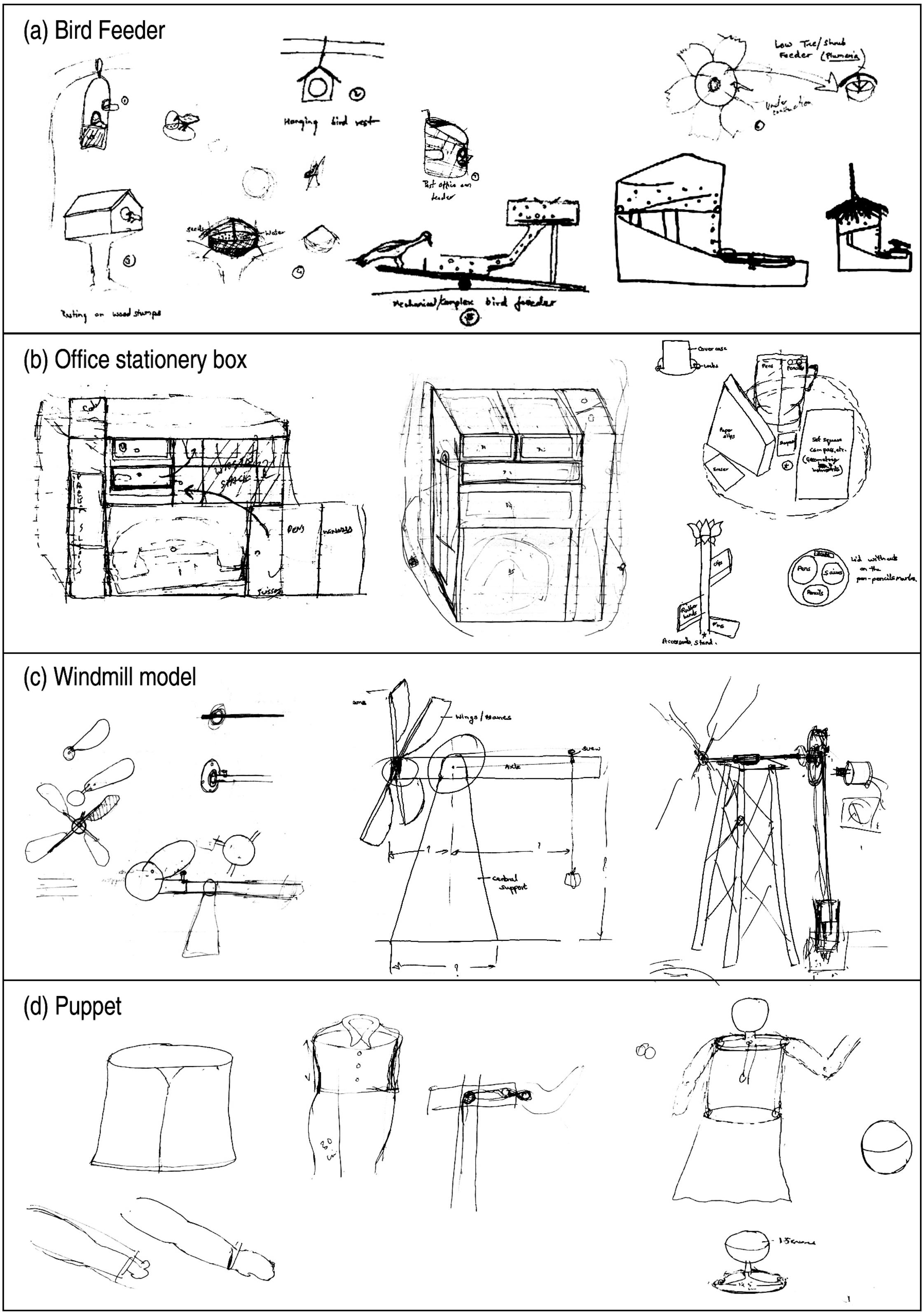


Fig. 4.2: Researchers' explorations.

The list of potential D&T units were categorised as in Table 4.3 in terms of the two axes of increasing complexity (row) and decreasing familiarity (column). The list is not exhaustive but certainly helpful in judging suitability of the units for the trials.

Table 4.3: The potential D&T units for middle school students in a complexity-familiarity space

Familiarity	**Complexity**	
	Simple	***Complex***
High	Card	Wheel barrow
	Bag	Mouse trap
	Newsletter	Map of a place
	Kite	*Puppetry*
	Recycle bin for assorted waste	Airplane
	Tiffin box carrier which does not allow oil spills	Water harvest and recycle system
Low	Boomerang	Automated seed dispenser
	Herbarium	*Windmill*
	Catapult	A coin sorter
	Terrarium	Teaching/learning aid for visually challenged
	Glider plane	A pram for a disabled child
	Bird feeder	A signal alarm system for earth tremors/ calamities

4.3.4 Content of D&T units

Besides considerations of familiarity, complexity and manifestation of the artefact, the unit selection was influenced by our understanding of local technological practices, students' exposure to material resources and their skills in handling materials, as well as their preparedness for concepts that could be taught through a unit.

We briefly analysed the syllabus of existing school subjects from Class 1 to 8 (age range 6 to 13 years) with respect to the inclusion of creative, manual and practical work components in them. These included syllabus of the school subjects – Art and Work experience – prescribed by the Maharashtra State Board. The stated aims of course include the intellectual, emotional, physical and social development of child. Visual and performing arts includes skills of drawing, making artefacts, music and drama, which were a part of Art syllabus. while theoretical explanations of the structure of common technological artefacts such as iron, radio, etc. were a part of work experience curriculum. Visits to a few English and Marathi medium schools in urban and rural settings provided the field exposure.

Besides their prior school experiences and learning, students bring to class their experiences and exposure to materials, other resources and skills in out-of-school settings as well. For example, middle school students (aged 11-12 years) may have had an exposure to basic skills of cutting, joining (gluing, sewing) and assembling things, either in school at the primary level or through their everyday chores. Likewise, middle school students were exposed to estimates and measurement concepts in their mathematics classes. Technological activities can provide opportunities for middle school students to visualise spatial concepts like length, area and volume, and use estimation skills in combination with concepts of measures and scale in authentic task contexts.

The artefacts in the list in Table 4.3 were re-categorised as follows on three sets of criteria.

1. A familiar, simple, static artefact of individual use, simple enough to be designed and made by an individual, and involving familiar materials, procedures and skills

2. A dynamic mechanical device designed by groups to serve a community of users; the device involving several components, varying materials and complex assembly; requiring knowledge of materials, joints, compatibility, tool use skills and procedures

3. A system involving multiple objects and assembly; using learned or easily learnable skills; organised by several people working together to serve a social purpose using knowledge of socio-cultural behaviour.

The 3 criteria along with an exemplary artefact for each are listed in Table 4.4. The table also lists the knowledge aspects from different school subjects that can be addressed in the design and making of each artefact. Besides science, the subjects include mathematics, history, geography, economics, civics and citizenship, language, ecology, etc. In fact, technology is seen here as trans-disciplinary and it appropriates the knowledge from several subjects.

Criteria	**Exemplar units**	**Knowledge aspects considered (Transdisciplinary)**
Simple, Static, Familiar, Individual	Bag	Geometric space of the container, relative dimensions, reinforcements (at the base and along the edges), idea of distribution of forces, zones of stress, etc.
Complex, Dynamic, Known object but unfamiliar assemblies, Made by individuals for social use	Windmill	Friction due to wobble, centre of gravity for a rigid body, torque, manipulation and translation of forces (rotational to vertical), relative proportions of components, distribution of weights, etc.
Complex, Dynamic, Familiar, Social purpose	Puppetry	Relative proportions, body joints and movements, role of perceptions and stereotypes, co-ordinated management of resources, team-work, fine-motor manipulations, voice modulation for effective communication

Table 4.4: Artefact themes chosen as the D&T units

Apart from the above considerations, the ability and exposure of students to tools and material resources were also taken into account. Some activities integrated with the D&T units may serve as authentic contexts for teaching domain-specific content. The content may be related to the larger activities within the unit. Examples of these include human body joints from biology, measurement and quantitative estimation from mathematics, reinforcements, tool use, and representations from design and engineering, history of artefacts, etc. Besides, students need to relate function to material properties and structure. Opportunities were structured for students to use diverse modes of expression like gestures, drawings, models, verbal modes, etc. Such opportunities encourage students to transcend the disciplinary boundaries emphasized in the existing school curricula.

4.3.5 The three D&T units

The artefacts listed in Table 4.4 were used for developing the three D&T units. The choice of the combination of units were made so that they included activities that would appeal to rural and urban students, as well as to girls and boys. For each unit, the requisite knowledge and skills as well as the concepts, procedures and skills expected to be acquired through the unit are briefly described below.

Bag-making: Design and make a bag to carry a few books (at least 5 which included a notebook, textbook, hardbound book, paperback book and another book) to a friend's place. Bag is a simple, static and familiar container/artefact used by men and women of all age groups, rich and poor, urban as well as rural people, in many cultures across the globe. Meant for the prime purpose of carrying things around safely, holding and storing things, bag has a single component or at best is simple assembly of a few components. Primarily intended for use by an individual, a bag offers a rich variety: it can have different shapes, could vary in size, could be made of different materials, involve judgements of handling, use and may even have specific preferences and utilities (a special case for holding a bottle, pen-pencil spaces, etc.). Bags connote fashion trends and often communicate messages through its design. A familiar yet diverse product, would offer enough scope for individual preferences. Relevance of the artefact can be suitably contextualised for different settings. For example, a slate along with books was a slight modification made for the rural sample. The unit addressed the following content:

Pre-requisites: Bag requires simple skills of estimation, measurement and scaling, drawing, cutting and fastening. Skills of paper-folding and visualisation may help forsee the outcome of folds and bends.

Knowledge (conceptual) content: a container concept, graphical knowledge of representing dimensions on 2-D, concepts of bending and pulling strength (in case of handles), joints and reinforcements and aesthetics.

Procedure and skill content: Skills of different kinds of cuts, skills of representing static 3-D artefacts on 2-D (paper).

Windmill model: A working model of a windmill that can lift given weights. Windmill is a complex, mechanical, stationed device that is a collective of multiple dynamic objects functioning together as a system of organised output, meant for social use. The windmill model involves an assembly of several components, of which, tower, axle and vanes, need elaborate design. Mechanical functioning of the device involves relational dependency on parts, as in the transfer of motion brought out by rotation of the axle about its horizontal axis causing the vertical lift to happen. Besides emphasizing the process aspect of technology, the problem presented to students was in the form of a story in which the context of lifting water from a well or reservoir was used, a problem common in many villages.

One of our findings in our survey study was that students perceived the fuel-run, mechanical devices as involving *high* technology as opposed to simple mechanical devices which were considered as involving *low* technology. Windmill presents itself as an ideal contextual example of a technological artefact, which fits into the category of mechanical devices and yet does not require fuel for its operation. Besides, the natural context of a poor electric supply and wide discussions on wind as a potential resource for renewable energy in the media provided the impetus for taking up the activity. It is an artefact of social use but one built with a collaborative effort.

Besides, India is looking forward to windmills as a potent source of renewable energy. Efforts to realize this have been initiated through installation of windmills in the States of Maharashtra, Gujarat and Andhra Pradesh. Windmill is often quoted in school textbooks as an example of renewable source of energy and also in the context of translation of mechanical to electrical energy. All these considerations provided the motivation for choosing windmill as a D&T unit. The unit addressed the following:

Pre-requisites: Elementary ideas in aerodynamics (surfaces that afford drift, ideas for using wind to propel objects), idea of rigid structures and motion mechanisms. Basic skills of assembling and ability to use general tools such as hammer, pliers, etc.

Knowledge (Conceptual) content: concept of a mechanical device, a process involving assembled components to a functional system, aspects of stability in structures, idea of mass distribution (tower design) and counterweight, knowledge of material appropriate for specific purposes, idea of wear and tear, bending and lifting strength, joints and reinforcement, idea of torque, translation of motion, mechanical advantage and minimizing play (energy loss).

Procedure and skill content: Specific tools use (drill machines, saws, cutter), skills in representing complex assemblies, team work, decision making and task management.

Puppetry: Design and make a puppet character among each group, which can be manipulated with hand (glove puppet) and stage a collective performance. A coherent system of performance required students to take into account the physical appearance and character profile of the puppet, which inturn should gel with the storyline. The number of characters were the same as the number of groups (6 in our case), who chose one character each through consensus. A balance of male and female characters was also encouraged.

Puppetry, as a source of human creativity and entertainment, a traditional art form, has had an important place in many societies across the globe. In its diverse forms, puppets symbolise regional practices and has been an integral part of our cultural heritage. Puppetry, a people-centred activity involves people participation and has been widely used as a valuable tool for communicating and disseminating ideas among masses. Often it has been used in sensitization programmes to spread awareness among people about diseases, literacy, education (girl-child and child education), etc. and can also serve as a pedagogic tool. It affords a greater facility to accommodate diverse cultural codes (dress codes, symbols, portray ideas and personalities) and may appeal to all class of people, irrespective of age, sex or socio-economic influences. As a technological system, it offers scope for imagination and creative visualisation, allowing artefact-mediated, human-like (animistic behaviour of artefacts) expressions of habits, speech-patterns and life-style.

In our survey study, we found that electronic devices in general and particularly the communication artefacts were rated as involving *high* technology. Puppetry represents a social means of expressive communication which does not need electronic gadgets but instead relies on time-tested indigenous modes of social communication. Such a combination involving collaborative work would attract urban and rural children alike, girls as well as boys. This unit involves two levels of collaboration: collaboration in designing and making activity and collaboration in staging a successful performance. This unit addressed the following content:

Pre-requisites: Idea of body joints and range of possible movements, cultural symbols and meanings, expression through body language and gestures, knowledge of joints and stitches and free motor manipulation of hand.

Knowledge (Conceptual) content: a social system in which individual performance structure resultant outcomes, idea of joints and reinforcements, aesthetics and structure-function relations (human hand-span and its effect on manipulating puppets), knowledge of cultural attires, tones and accents, behavioural patterns and values that inadvertently shape the puppet character, sewing skills, co-ordinated movements.

Procedure and skill content: Skills of making, manipulation, co-ordinated working and presentation (dialogues and delivery in relation to light, stage settings and other objects) and organized team-work.

Before the trials, researchers themselves worked on making each of artefacts: bag, windmill model and a puppet. The exercise of going through the process of making helped researchers' appreciate the entire process of design and make on one hand, and helped explore the potential problems that may arise in designing and making on the other. Researchers consulted several resources: print (books, magazines, newspaper clippings, etc.), electronic media and even consulted experts (puppeteers) to learn more about the processes and skills involved in making. For example, even for a simple and familiar object such as a bag, understanding of different kinds of folds is needed. Bags and boxes were explored to get ideas of the different kinds of folds. This also allowed scope for thinking of effective measures to resolve problems arising during making well in advance. Such explorations helped researchers/teachers to get a meta-view of the entire activity and helped structure the units to draw students' attention to concepts, facts, specific issues and problems.

Sequence of the trials

The structuring of the three units for classroom practice was guided by complexity of tasks involved. Our assumption was that a unit on bag which involves elementary skills of making (cutting, folding, gluing, etc.) would serve as a springboard for other units that demand a higher level of complexity. The last unit on puppetry represents a system, involving two levels of planning and execution. The sequence of trials for the three units in the three settings and their time schedule is given in Table 4.5.

Table 4.5: Schedule of trials conducted in the three settings.

D&T Unit	**Setting**	**Period of trial**
Bag	Urban Marathi	18, 21, 23, 25 and 27 August 2003
Bag	Rural Marathi	06 and 07 October 2003
Windmill	Urban Marathi	12, 13, 14, 15, 16 and 17 April 2004
Puppetry	Urban Marathi	19, 20, 21, 22 and 23 April 2004
Bag	Urban English	03, 04, 05 and 07 May 2004
Windmill	Urban English	10, 11, 12, 13 and 14 May 2004
Puppetry	Urban English	17, 18, 19, 20, 21 and 22 May 2004
Makeup sessions	Rural Marathi	02 and 03 July 2004
Windmill	Rural Marathi	15, 16, 17 and 19 July 2004
Puppetry	Rural Marathi	10, 25, 26, 27 Aug. and 01 Sept. 2004
Interactive session	All 3 schools	29 September 2004

When the trials of all the 3 units in the urban settings and the bag-making unit in the rural setting were completed, the researchers realised that rural students were shy and had been least articulate of all. They needed more time than we could give in the first unit to become familiar with the ways of the researchers. Hence, a separate session, named "Makeup session" was conducted in the rural Marathi setting. The games and other activities structured in the session were intended to convey several ideas: the idea of having rules or structured behaviour in any activity just as in games, ways of chunking and categorising objects around them such as plants and their leaves, engaging in design as in a designing a postage stamp. The opportunity was also used to expose students to other skills needed in the units such as teaching measurements and sewing.

4.3.6 Cognition and technology education

D&T education units for middle school students had to take into account the cognitive readiness of students for the tasks and analysis required of them. Then alone could students gain cognitively from the D&T tasks. The following tasks were built into the design of the units, where students' cognitive involvement in tasks was made explicit.

- negotiation and exploration of design ideas among students seen while groups engaged in making the exploratory sketches

- written descriptions and poems about artefacts
- communication of design by students
- drawing-up the plan of making
- evaluative accounts of products and their performance

Students were requested to maintain all their paper-and-pencil work in their group portfolio. The typical contents of a group portfolio is represented through a visual in Figure 4.3. All productions of the group were recorded: the paper work in portfolios and actions and oral production in the form of audio and video tapes. Models made by researchers, both failures as well as the working ones, were preserved and served to stimulate reflective discussions among students during their evaluative accounts. All the design productions, other paper-pencil productions and products helped students reflect on their actions and provided researchers the means to investigate the progression of students. The cognitive aspects of technology education as seen through students' design productions are discussed in Chapter 5, section 5.5.

4.3.7 Teaching D&T in schools

Structuring the unit in terms of the content, needs to be complemented with a careful tailoring of the process to convey the content. Shulman (1986) while discussing the knowledge aspects in teaching has emphasized the need to blend content aspects of teaching and the elements of teaching process, especially so for an integrated discipline such as D&T education.

The situated paradigm of learning recommends activities to be authenticated so as to maximize its appeal and engagement. Any engagement, especially for a design and technology unit, needs to motivate students in order to reciprocate willful and active participation in the engagement. Shulman (1986) while discussing teacher knowledge of a domain identifies elements of content knowledge in teaching to include three categories of knowledge: (a) Subject matter content knowledge, (b) Pedagogical content knowledge, and (c) Curricular knowledge. Content and curricular knowledge have

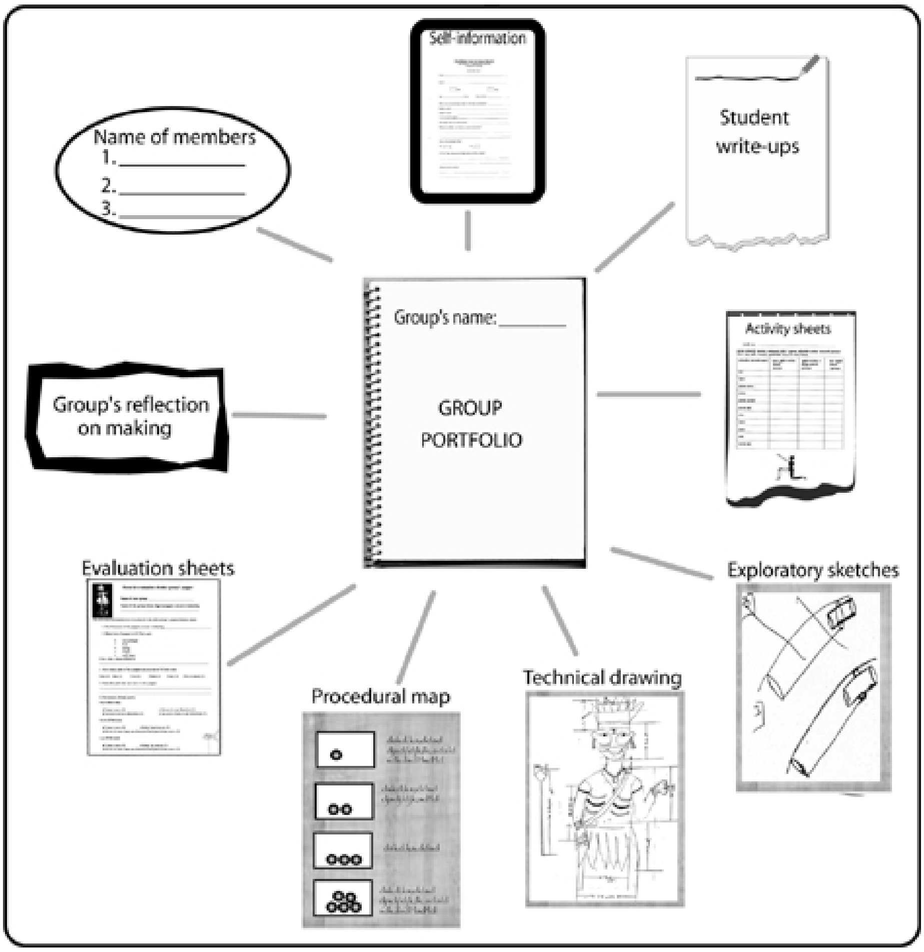


Fig. 4.3: Visual representation of the contents in a typical group portfolio.

already being discussed in earlier sections. Pedagogical content knowledge (PCK) refers to ways of representing and formulating the subject that makes it comprehensible to others. Students' conceptions (pre-conceptions and alternative conceptions) and strategies for reorganizing are to be taken into account to make learning more fruitful. Besides, he notes that the role of pedagogical knowledge of teaching, which involve generic principles of classroom organisation and management are also important. The teacher background also plays a crucial role in the way a D&T unit gets facilitated. Our research group was an eclectic group with 4 researchers (2 research students and 2 supervisors) with diverse academic backgrounds as physics, psychology, nutrition and botany.

Structuring collaboration

Most activities required students to work in collaborative groups of 3 to 4 individuals each. Students in each setting were requested to form the following groups of 3 to 4 members: two groups of girls, two of boys and two mixed sex (boys and girls) groups. We observed that the formation of the two mixed-sex groups was easier if it was addressed first, that is, students were first requested to volunteer for mixed-sex groups. Shy students preferred to be in an all-boys or an all-girls group.

At the beginning of the first unit, each group was asked to think of a name by which the group would be identified throughout the unit. Besides defining a common identity, a group name motivated the members to work together to achieve a common purpose. They then felt a sense of ownership of the productions. Each group maintained a portfolio of the paperwork of its members. Students could refer to these productions. The portfolio helped researchers track the progress of the group.

The transaction of each unit in the classroom was guided by a loosely structured sequence of activities, which are listed here and described below. The pedagogical model that integrates these activities is referred to as *Collaboration and communication centred D&T education model for the Indian context* as given in Figure 4.4.

1. Motivation and investigation
2. Design exploration
3. Technical drawings
4. Plan for making
5. Communication of design and plan
6. Making: Implementing plans through actions
7. Planning and implementing the system (for systems only)
8. Evaluation and reflection

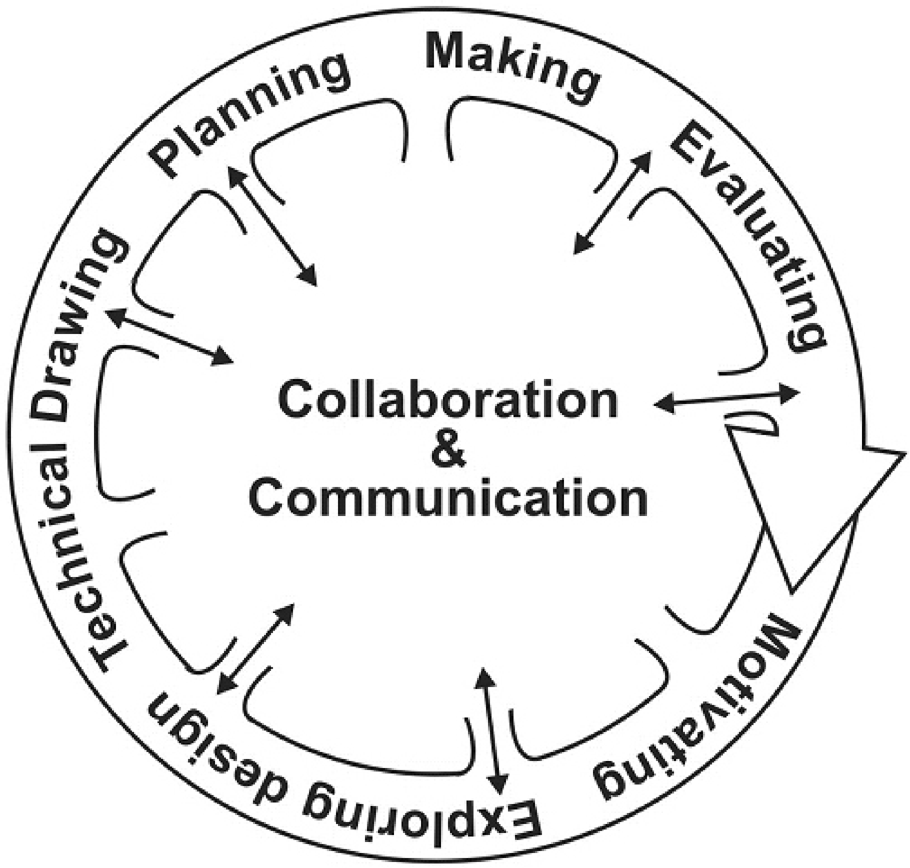


Fig. 4.4: Collaboration and communication centred D&T education model for the Indian context (Choksi et al. 2006).

Motivation and investigation

Learning contexts should be suitably tailored so that students get motivated to engage in learning activities (Stipek 1993). The researchers perceived the artefact as a potential solution to a problem context. Negotiating a shared understanding of a problem context was hence seen as a vital part of the D&T units. Several strategies were probed to achieve this: through presentation of a historical anecdote or a story; discussions of immediate experiences of a visit to a locale or an event. Even discussions of students' interests, hobbies and leisure activities may serve as contexts for negotiating problem situations and for introducing the artefact as a solution. The different strategies also served in problem scoping and set the direction for gathering information relevant to the problem.

To initiate gathering information and design investigation, students were shown a large variety of artefacts relevant to the solution of the problem context. Students could get a flavour of the variety through different modes such as print sources (pictures, photographs, line drawings, school textbooks, reference books, children's magazines, newspaper articles), media (animated clips, videos, internet sources), models of artefacts or through other means (like a visit to a puppet-show, a workplace or a museum). A good collection of information about the artefact helps to present the context in a better way besides aiding students to make appropriate associations with ideas across other disciplines. Students could explore the artefacts: its structural, functional, material properties, purpose and other design aspects. They were encouraged to talk about analogous artefacts, share their ideas and experiences. If artefacts were not within easy reach, visuals and models were used to draw students' attention to these aspects of artefacts. Investigations help in engaging students in deeper issues of design and manufacture. This is in contrast to the approach of following prescribed or known procedures. Thus, the overall aim of the phase is to prepare students to engage in authentic design problem-solving situations. The structure allowed variations from one unit to the other as indicated below.

Bag-making: The common experience of carrying objects in a variety of containers was capitalized to motivate students to think of a means to carry five books to a friend's place. The solution was conceptualised by the students as a bag. However, the nature of this bag was open to further negotiation within groups. Students were encouraged to explore the different kinds of bags in their homes and the market. Some brought samples of bags to class, where they were shown bags of different sizes and shapes made of different materials like cloth, jute, paper, etc. Pictures of some bag designs were also shown (see Figure 4.5). Based on these experiences, a discussion was initiated in the whole class on the features of bags, such as its size and capacity, nature and position of the handle, joints and reinforcements, etc. which has been summarised in Table 4.6. Information of materials, design and purposes flowed in their descriptions of several kinds of bags. For example, a bag with beads, *ajicha batwa* (translates to grandmother's purse) – a small handy bag with compartments used for keeping medicines, a woollen bag with chain and a handle, a bag with a flat base with thick body and a handle. A few motivated individuals went beyond and explored making a model bag: one of them made a model of a paper bag while two girls made cloth bag models. Students were encouraged to speak more on the bags, at times even referring to the bags that they were carrying. Student investigation thus went beyond class discussions and they could talk about artefacts seen in home, shops, schools or any other context.

Fig. 4.5: Some bag designs shown to students.

Windmill model: A more elaborate strategy was used to situate the problem context of a windmill within students' direct or vicarious experiences. The toy windmill (English: pinwheel; Marathi: firki), with which all students were familiar, was used to initiate the discussion on windmills. Students from all settings had heard and seen pictures of windmills in their science textbooks. The goal of the D&T unit was contextualised through a story narrated to the students: the story of a village farmer, his wife and their two children. The family used groundwater for irrigation, and found it difficult to lift water in the absence of electric power. The children visited a village fair, bought a pinwheel and played with it. They discovered that it could lift a feather and used the idea to devise a way to lift groundwater: they made a windmill model. The story was suitably punctuated to make it interactive with feedback of students' experiences of a fair. The story session was followed up with initiation of dis-

Table 4.6: Issues discussed during the motivation and investigation phase in the bag-making unit

Aspects discussed	Description
Estimation of size	*Dimensions:* Length, breadth and width
Materials	*Materials used:* Jute, plastic, paper, cardpaper, cloth, recycled paper, natural fibre, nylon, wool, etc.
Properties	Strength: *Carrying capacity:* approximate estimates of weights or objects carried Durability, flexibility, etc.
Handles	*Number:* 1, 2 or 4 *Position of handles:* Along the sides, Through the two big surfaces, circular along the mouth as in a traditional purse, etc *Strategies to fix handles:* Knots, Glue, Rivets, Stitch, Weave, Embed
Other features	*Shape:* Round, Oval, Rectangular, Squarish, hexagonal *Orientation:* Horizontal, vertical

cussions about windmills. Small variations were made in the story in order to appeal to the students from different socio-cultural settings.

An activity where students had to recall names in their own language (non-English) led to discussions of the contexts in which they were coined. Following the discussion around *firki*, each student was given an opportunity to handle one. Each one among the rural students made a pinwheel using pin, paper and drinking straw following the instructions provided to them. Students were then asked to draw the *firki* in front and side view (object drawing). This activity helped direct students' attention to the different components, assembly and its working. Students used diverse graphicacy techniques to bring out the subtle features of a known object as a firki. They used techniques for shading (shaded the curved surface of a vane, darkened edges, etc.), used relative darkening of contours to distinguish the levels, etc. Their comfort in making drawing of a familiar object was also a confirmation of their ability to use representative techniques for depiction. However, most of them struggled with depicting the side-view.

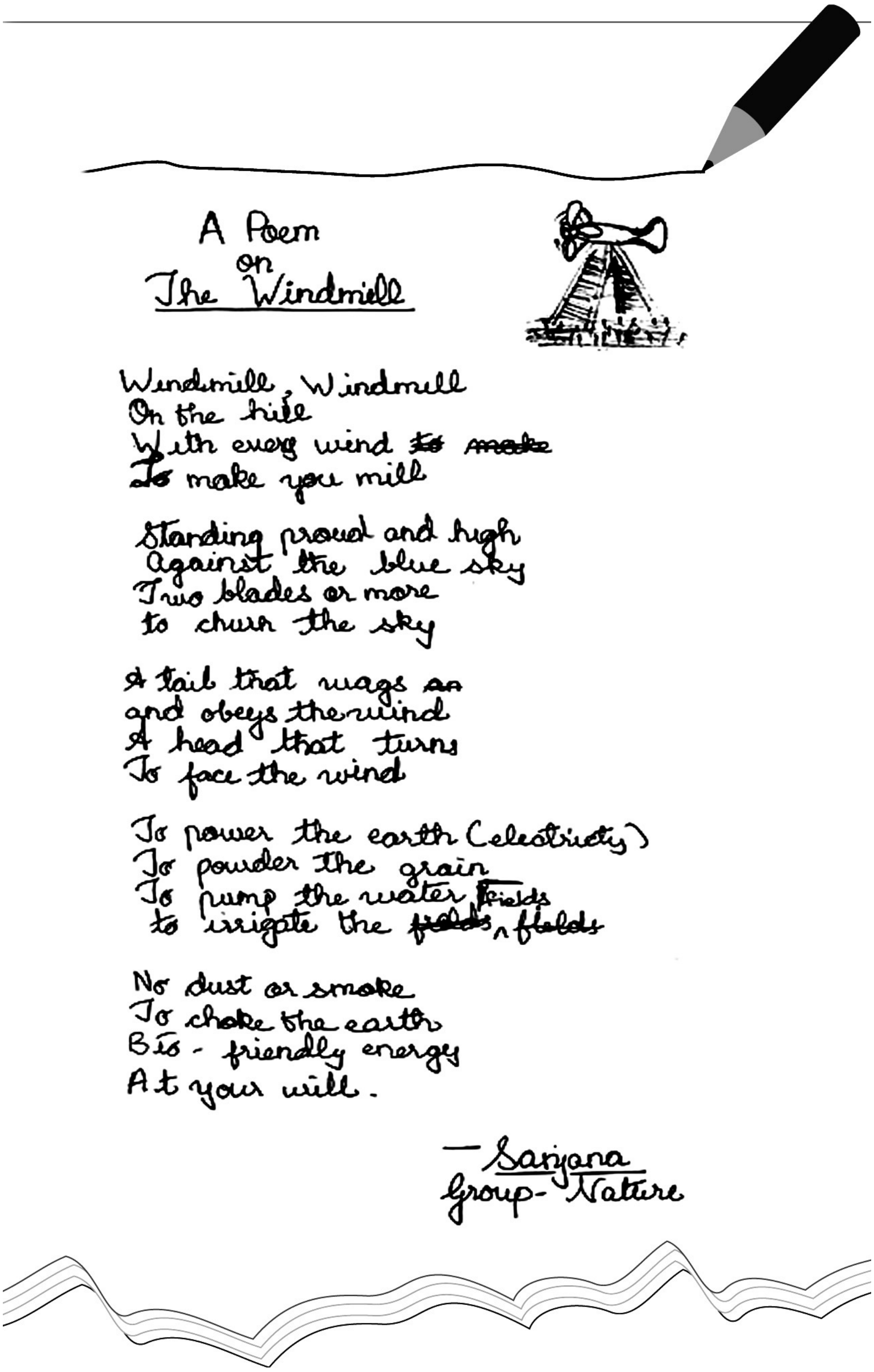
Care was taken to include activities and discussions that would help students develop the technical language needed to collaboratively design a windmill model. Students were shown visuals in books, magazines and newspapers, computer animations and short movie-clips of a variety of historical and current windmills used for different purposes. Students were primed to notice structural and functional attributes of the windmill in the pictures and models shown and were provided with suitable words to describe its components. They were encouraged to write a description or a poem on windmills. Figure 4.6 is a poem by an Urban English group.

Puppetry: The researchers had set the goal of the unit as making puppets and staging a show. This was contextualised through discussions and investigations grounded in students' personal experiences of stage-shows, theatre, plays and performances. The sharing of experiences was followed by the students seeing and handling dolls and toys, stick and finger puppets, hand/ glove puppets, and marionettes in animal as well as human forms. They were primed to explore the similarities and differences in their structural and functional mechanisms: list the kind of movements (motion) and expressions (emotions) that could be demonstrated using the puppets. Such an exercise helped them get a feel of handling puppets as well as explore the subtle expressions and possible fine motor manipulations.

Space for discussions among students aimed at developing their language skills. Students were asked to provide different words for "puppet". Besides, each of the six groups had to write a story with 6 characters and present their stories to the class. After communicating the stories to the class, the different groups had to concur on one of the stories to stage a puppet show. We suggested that the stories selected should have a gender balance in the characters. Each group selected a character from the chosen story.

In order to provide the knowledge and skills needed for designing we used a number of simple games and audio-visual demonstrations to discuss human body symmetry, proportions and joints with their movements. Each group filled a worksheet that encouraged collaborative learning combined with fun. The worksheet required them to explore the different kinds of joints and possible movements of joints in their own or their friend's body. This activity at the close of the phase on investigation and motivation helped students get used to the formal vocabulary as well as the relevant scientific information.

Symmetry in body parts and relative body proportions was discussed through a number of examples (cartoons, toys etc.), where deviations from normal sym-



A Poem
on
The Windmill

Windmill, Windmill
On the hill
With every wind ~~to make~~
To make you mill

Standing proud and high
Against the blue sky
Two blades or more
to churn the sky

A tail that wags ~~an~~
and obeys the wind
A head that turns
To face the wind

To power the earth (Electricity)
To powder the grain
To pump the water fields
to irrigate the ~~fields~~ fields

No dust or smoke
To choke the earth
Bio - friendly energy
At your will.

— Sanjana
Group- Nature

Fig. 4.6: A poem by an Urban English group.

metry and proportions are strategies to draw attention to certain personality traits. Games like *dumb charade* and discussions of *mudra* (as in dance) and sign-language to communicate with the deaf encouraged students to explore a variety of modes of communication relevant to puppetry. These games demonstrated how perceptions shape our thoughts and we tend to form impressions about people from their physical appearances. Cultural aspects reflected in individuals' dress, accessories, speech, dialect, behaviours, etc. were also discussed. A few examples of visuals used to initiate these discussions are given in Figure 4.7. We hoped that the students would integrate these ideas in designing their puppet character.

Design exploration

Interactive discussions during motivation and investigation led students to think of alternatives for the problem at hand. Students investigation of artefacts through various modes (visuals, clips, real-objects or models) channel their ideas toward developing a plausible workable solution. Each group had to come up with an agreed upon design idea of the artefact. Students had to explore the design of an artefact their group would make, by engaging in discussions, which often involved a lot of non-verbal modes of communication like hand gestures, sketching on sheets of paper and negotiation of ideas. An example of an exploratory sketches made by an urban English group while exploring their windmill model is given in Figure 4.8. Once the group had formalised some idea, the group then had to make a detailed drawing of their conceptualised artefact. The progression of activities through the design stage varied in different units as indicated below.

Bag-making: Students had to think of a bag of their choice for their group. They had to negotiate their ideas of shape, size, materials and the subtle features of design within their group to arrive at one design idea of their favoured bag. Some students even made small paper or cloth models. They also had to explicitly list its qualities.

Windmill model: Students had to visualize a multicomponent, mechanical device which could lift the given weights. They worked in groups to ideate the structure and assembly of components, visualize the materials to be used and the functioning of their artefact. In all settings, group members negotiated the design of a windmill, thus generating a group design drawing.

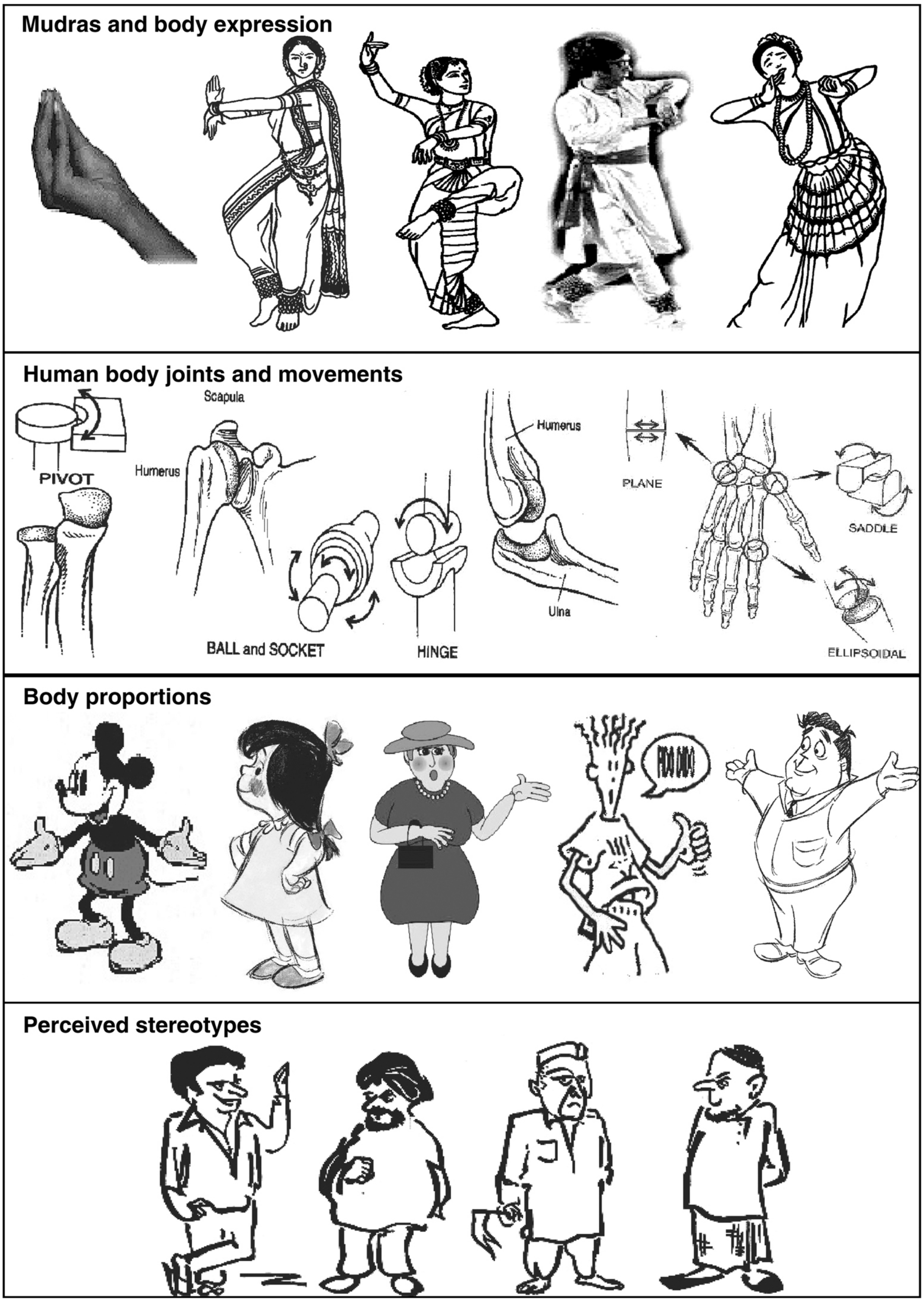


Fig. 4.7: Visuals used to initiate discussions on design aspects of puppet.

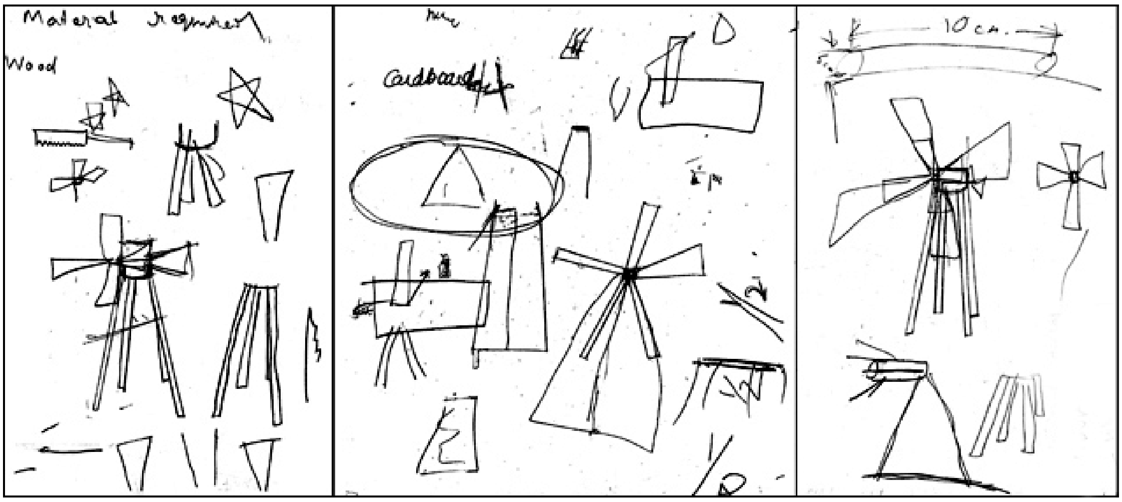


Fig. 4.8: Exploratory sketches of a windmill model by a mixed sex urban English group.

Puppetry: Among the stories suggested by the several groups, the class had to select one through consensus. The selected story had to have 6 characters, all preferably human. In cases of divided opinions on the story, the researchers facilitated discussions on some criteria such as the number of male and female characters, a variety of characters, etc. In the selected story, each group then had to choose a puppet character to make. Each group had to describe their puppet giving details of their puppet's personality in terms of its physical features, dress, behaviour, and language. In every setting, each student made exploratory sketches of their group's puppet character. The group, through negotiations, selected one of the sketches for further exploration. They chose the character's details, sometimes combining the details of different members.

The students then went on to make a technical drawing based on the conceptualised sketch.

Technical drawings

The *technical drawing* of their artefact made by a group, had to include details of their design such as, the size of components with their dimensions and units, the relative locations of components and the overall size of the artefact. Such activities engage students in using measurements, estimating proportions, and skills of depiction in representing their design ideas. After drawing these details, groups had to list the materials required to make the artefact and their quantities. They also had to estimate the cost of material resources. Students were told that all material resources that they listed for making would be provided.

Following the first day of trial of the first unit (Urban Marathi), we noticed that students had problems with representing artefacts in perspective in their design explorations of the bag. Hence, on the second day, a formal half-hour session was included on perspective drawings taught by an artist and science educator. This session included blackboard demonstrations using common objects as table, boat, bucket, etc. and some practice exercises for students. Using ideas of measurement, proportions, and perspectives, students had to draw the bag design selected among their group. Students were asked to revisit their bag designs and could now modify their earlier ideas. However, the problems persisted.

Little change was noted in the depictions of students and so we tried a different strategy. Idea of perspective was tried to be conveyed through discussing how a simple 3-D object as a cardpaper box could be seen from various angles. Students had little knowledge or exposure to the technique of depicting object dimensions on paper. The researchers realised this problem and hence in the next two trials in the urban setting, an hour long session on the role, significance and conventions in technical drawings was introduced. This included the use of notations for depicting object dimensions with units following the convention of leaders, arrows and end lines. The session was a mix of demonstrations and practice exercises involving a range of object shapes like discs, cylinders and cubes. Students measured them and drew as many views as were needed to depict the dimensions. Such a session was conducted in the Rural Marathi as part of the "Makeup session". Following this exposure, all students were observed to use conventions in their subsequent drawings, suggesting that they had internalised the role of conventions. The technical drawing made by the urban English group shown in Figure 4.9 is a follow up of the design explorations depicted earlier (see Figure 4.8 for exploratory sketches).

Technical drawings helped students to focus on the details of dimensions, assembly, structural attributes and the overall output, thus steering them to better visualise the artefact. The similarities and differences in the activity between the 3 units can be gauged by the descriptions given below.

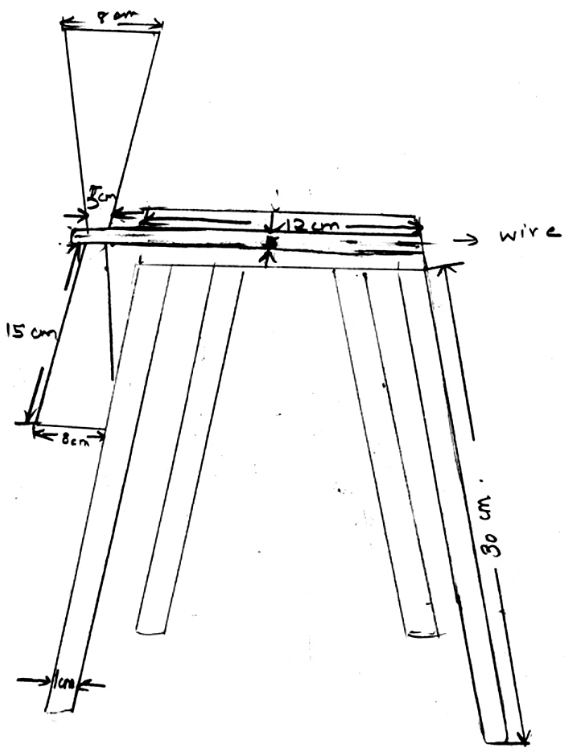


Fig. 4.9: A technical drawing by the group whose explorations are depicted earlier (see Figure 4.8).

Bag-making: Students in all settings had problems representing a bag in 3-dimensions (3-D). Students in all settings required some prior exposure to the graphical skills of representation. Their struggle with 3-D depictions and their problems of showing proportions and dimensions led researchers to refine the structure of the unit in subsequent trials to include a one-time exposure to conventions of technical drawings and exercises on estimating proportions. With the Rural Marathi, this session was part of the "Makeup session".

Windmill model: Students in the three settings continued to use the conventions of technical drawings to make their drawings informative. Students had to make a choice in the orientation of windmill model and number of views in order to depict the details of the complex assembly of components.

Puppetry: Students continued to use conventions of technical representations. The relative proportion of body parts was significant and students had to visualise that.

The details of an artefact represented in technical drawings had to be expressed through the form of an anticipated plan of action.

Plan for making

The artefact had now to be seen in the light of actual making. Students could be oriented toward actualising the concepts in the design by engaging them in visualising a step-by-step plan for the making of their conceived artefact. The production of this step-by-step plan of making has been referred to as the *procedural map*. A procedural map encourages students to look at details at various levels: at the level of a single component, at the level of assembly of two components and at the level of the entire artefact. This includes the process of assembling parts, visualizing the sequence of actions, etc. Besides, such design productions are a mental effort that could save the physical effort while making and may serve to maximize the use of resources (Mitcham 1994). Procedural map includes dual modes of representing the process of anticipated making: the visual mode of drawing the step and the written description of the process represented in the step. The example of procedural map depicted in Figure 4.10 follows the design explorations and technical drawings made by the same group.

During the trial of the first unit (bag-making) in all settings, a familiar context of making tea or lemon-juice was used to introduce the significance of procedure in making any artefact. In the first and second trials – bag-making in urban and rural Marathi settings – the tea making example itself was used to illustrate a procedural map as well. Students still found it difficult to visualise procedural maps and needed an exemplar. Hence a simple and familiar pin-wheel or *firki* was introduced during the windmill model trials in the Urban Marathi setting. An exemplar procedural map, as shown in Figure 4.11 depicting the description of steps with corresponding illustrations, was then displayed in the class so that students could study it. Subsequently, the English version of this exemplar was also used in the trial of bag-making in the urban English setting. This exemplar was introduced to the Rural Marathi students during the "Makeup session".

Each group had to make a procedural map for their artefact. They also had to identify and allocate tasks among the group members. The distribution of tasks helps pre-decide through consensus the responsibilities of members within each group and also

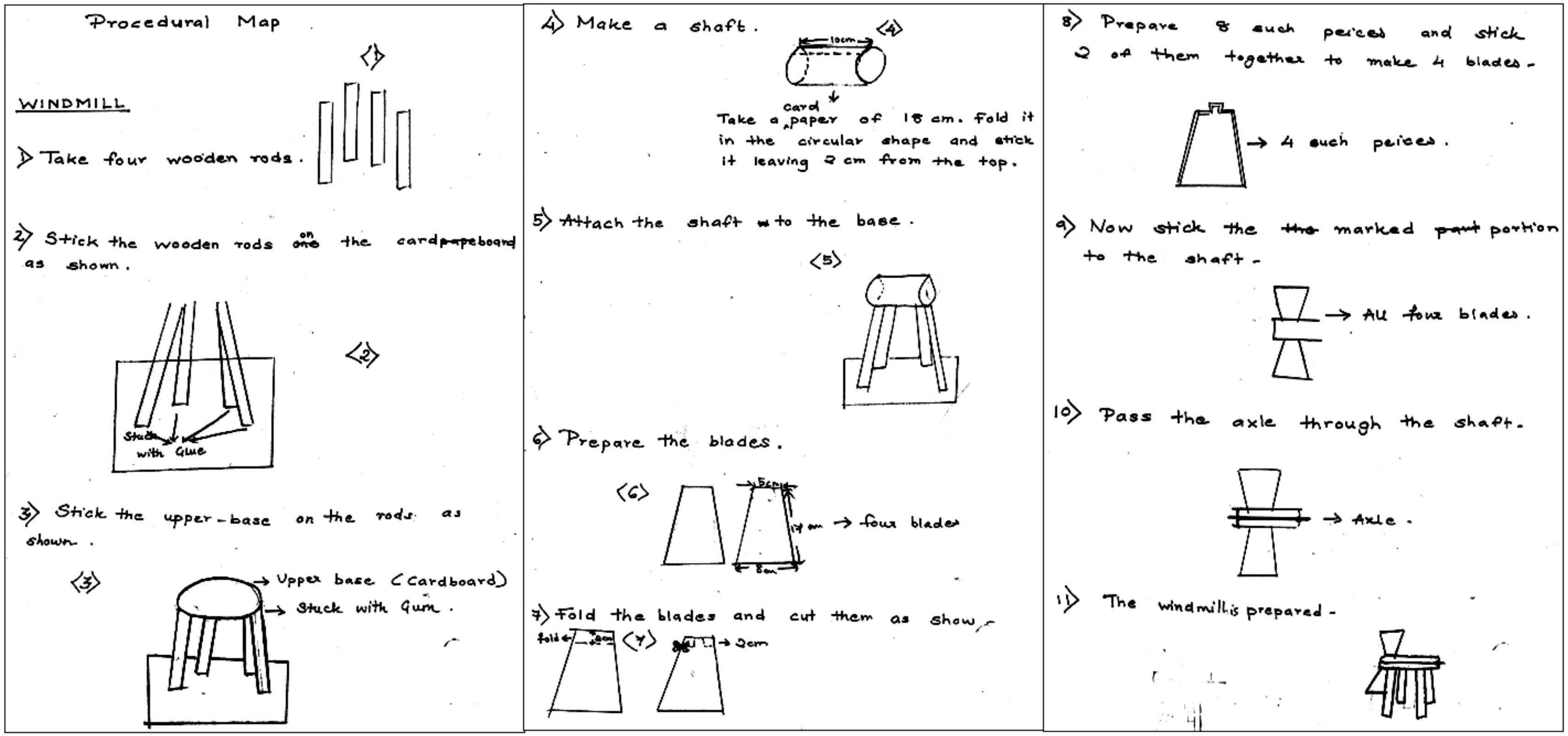


Fig. 4.10: Procedural map of the urban English group whose explorations (Figure 4.8) and technical drawing (Figure 4.9) are depicted earlier.

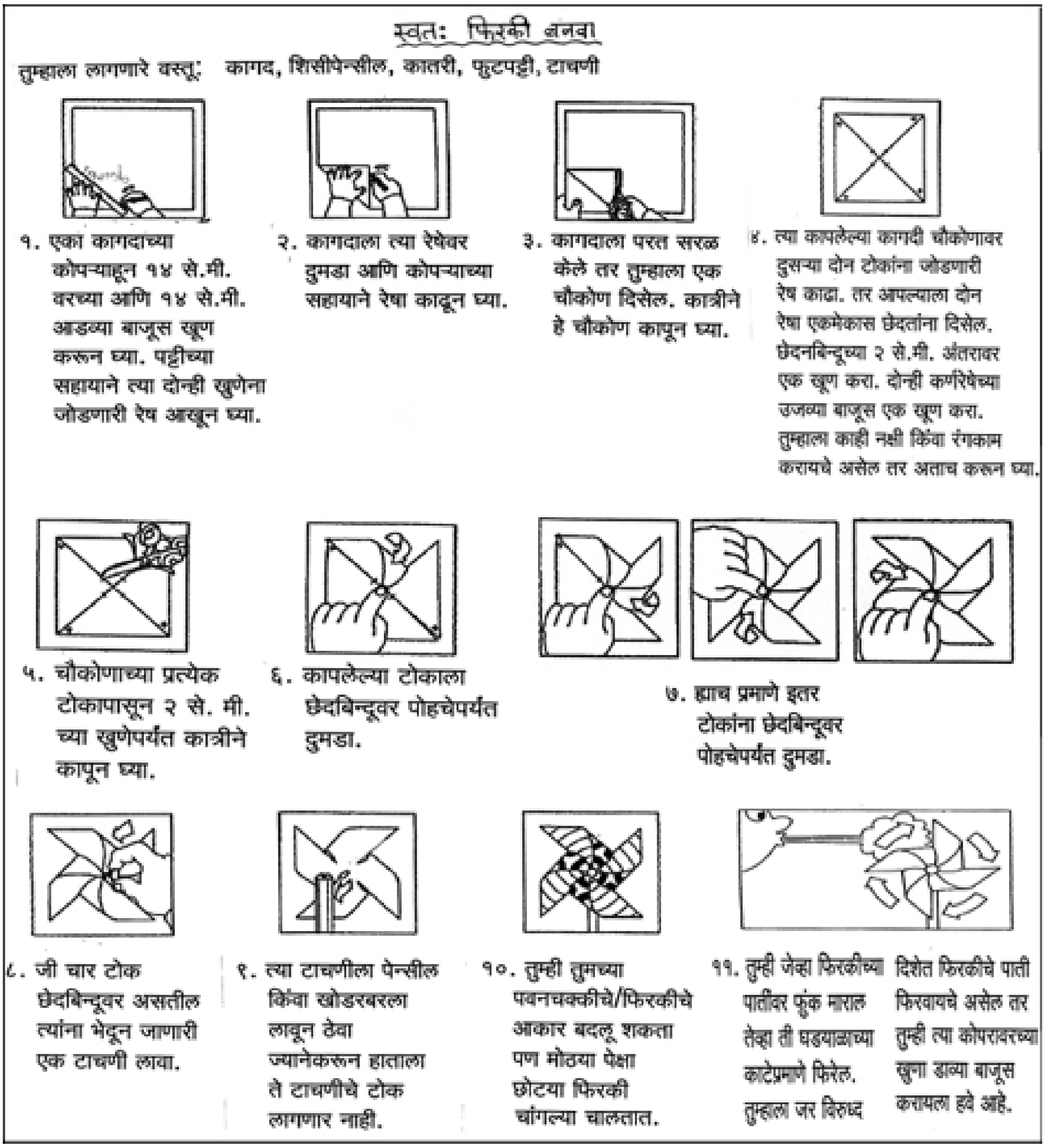


Fig. 4.11: Marathi version of the exemplar procedural map of a pin-wheel used in class.

ensures that each one of them contributes to the collaborative effort of the group. Each group discussed their group's design and making plans with other groups. Inputs from other groups sometimes led to modifications of their design.

There were a few differences between the three units in terms of the initiation and procedure of representation of conceptualized design. How these arose in context will become clear through the discussions of the individual units given below.

Bag-making: This unit has the simplest making steps, essentially involving cutting up the material in required shapes and sizes and suitably folding and joining them using familiar tools like scissors, glue, needle and thread. Groups had to identify and allocate the making sub-tasks like cutting, sewing, etc. among the members.

Windmill model: The plan for making this artefact was one of the most complex, involving several steps, and multiple stages of assemblies of components, some contingent upon others. In the unit on windmill model, involving a dynamic mechanical device (or system), more than in any other unit reported on here, the plan was a crucial step in the design. It enabled the visualisation of the anticipatory steps in the making.

Puppetry: By the time students arrived at this stage in the third unit, they were familiar with the design and make sequence in general, and in generating the plan for making, in particular. The plan at this phase involved the making of an individual puppet by each group.

Each group now had both graphic and textual depictions of their envisaged product. They were sufficiently familiar with their conceptual artefact that they could articulate their design.

Communication of design and plan

A formal presentation by groups, in any language of their choice that was commonly understood by their peers, was a part of the structure of every unit. These presentations were aimed at increasing interactions across groups, an open review of design ideas, and for encouraging constructive criticisms from peers besides offering an opportunity for honing students' public speaking skills. Each group presented their design to the class and sought suggestions for improving their design before they set to work on the actual making. Others could criticize, ask questions, raise doubts and suggest changes in design, materials or procedure.

All members of a group were encouraged to speak to the class in turns by reading out the different aspects of their design and plan for making. Groups could alter their design ideas following this activity. The content and structure of the communication in all the settings evolved through the three units, as the students gained in confidence and practice.

Bag-making: Being the first unit in each setting, students were initially guided to organize their presentation. It was suggested that introducing the group and its members to the audience was a good way to begin. They could then talk of how they arrived at their ideas, the factors that affected the choice of design by their group, the details of their design, including technical drawings, list of materials, procedural map and the distribution of work among members. Students were given time to organize their communication.

Windmill model: Students had become better at organising their communication and needed guidance less often.

Puppetry: Groups communicated their design and plan, which included the drawings and the character sketch. As in the other units, they could modify their artefact based on the feedback received.

After the communication session, students were shown a puppet designed and made by the researchers. Along with that, they were shown the exemplar paper templates. Referring to their technical drawings, students had to cut newspaper sheets to the required dimensions to make paper templates of different body parts and dress. They had to fit these together to get their desired effect. These were checked by the researchers for ensuring feasibility of making. Thus paper templates were used to estimate the cloth needed, and gave a rough idea of what the final product may look like. This could also reduce wastage of material due to unforeseen errors while directly working with the final resources.

By the end of the session, the groups were ready to take on the task of making. Each group was then given the materials they had asked for and the groups became immersed in making. In the case of the puppets, paper templates were checked before distributing the materials.

Making: Implementing plans through actions

Making involves transformation of material resources into desired artefacts guided by the design and anticipated action plan. Students collaborated in groups as they worked toward realising their design ideas. Besides the materials, tools and resources listed by students, additional tools and resources were placed on a table and were accessible to all groups. Students were encouraged to seek researchers' help in resolving problems arising while making. They could refer to their design ideas in their group's portfolio, and modify them if needed. Making involved students' active engagement and dynamic interactions with materials, tools and other resources under supervised guidance. The complexity of the task varied in the three units, windmill model being the most complex.

Bag-making: This unit involved use of common tools and resources familiar to students in all the three settings. Being the first unit, this was the first taste of the successful generation of a product that they had conceptualised. This set the stage for the following units.

Windmill model: The unit required several tools, many unfamiliar to students. Some needed to be used under supervision of the teacher/researcher. Developing skills of handling tools in a safe manner was an important part of the making activity in this unit. Students were given the names of the tools, their safe use was demonstrated, listing the precautions to be taken while operating them. The participatory and collaborative practices followed in this unit required the students to learn tool using skills by gradually increasing levels of involvement with the necessary tools in association with a competent person (the researcher) – from observation to working under supervision to independent handling.

Puppetry: Students used their paper templates, to cut the material. They did this for the several body parts: heads, hands, legs and overcoat. They had to stuff the head with cotton, rag-cotton or paper balls to get a 3D shape. They had to assemble the body parts and dress and add accessories following their character-sketch and design.

Unforeseen problems that affected the time schedules often came from students' lack of familiarity with the use of techniques. Time had to be devoted to teaching basic techniques of sewing in the Urban English and Rural Marathi settings.

Technological systems involve two levels of planning and design: the design and planning to make the individual artefacts that make up the system, and the design and planning of the assembly. In our case, puppetry was such a technological system that involved an additional phase, which engaged students in planning how each of the puppets already made would contribute to the puppet show - a collective system.

Planning and implementing the puppet show

The puppet (a finished product) is a part of the collective stage performance (a larger functional system). Together, the class had to put up a puppet show lasting about 10-15 minutes. After making their puppets, the groups dissolved and the students voluntarily reorganised themselves to form new teams, once in the planning stage and then again in the stage performance.

The planning functions (first 3) and performance functions (last 3) are listed below.

- Dialogue writing: The team rewrote the story in the form of a script for the play. The consensus in dialogue evolved with helpful comments and suggestions from peers.

- Composing music: The team was made up of students who either knew poetry, film and other songs or could render them as parody. They had to collaborate with the dialogue writers.

- Making props and stage-setting: The members of a team conceptualised the stage properties that would reflect the mood and ambience for each scene or situation. They designed and made the props.

- Puppet handling: The team members volunteered to handle the puppets, one from each group handling the puppet made by the group. The puppet handlers had to practice the movements required of them, matching the dialogue and music.

- Dialogue delivery and music: Facility with reading the script and voice modulation to suit the character and context was the main task of this team.

- Managing the stage lights: The team members were given coloured gelatine paper and light sources, which they could manipulate to highlight actions on stage. They needed to co-ordinate with the script writers, puppet handlers and the music team.

Teams received guidance and support from the researchers. Together the teams rehearsed their performances before the final show. They then presented the puppet-show before an audience which comprised of teachers, outside-class peers from the school and members of our Centre (HBCSE). This collective performance of individual puppets in the show after collaborative designing and making in groups was a second level of collaboration.

Evaluation and reflection on the making process

Groups carried out the evaluation of their own and others' products using a semi-structured evaluation format given by the researchers. This exercise aimed to encourage students to reflect on their design and making activity and organise their reflections. They had to critically appraise their own work using their language and presentation skills. Besides, it could help students realize the merits and demerits of the design alternatives used among all the groups to address the same problem.

The format included qualitative and quantitative criteria. Groups had to device their own ways of assessing their product based on the given criteria. Sometimes students used testing methods devised by the researchers to fill quantitative data on the functioning of their product, as in the case of the windmill model. Groups discussed the result of their evaluation exercise with all groups in a structured communication setting. Students were encouraged to evolve their own criteria and present their subjective evaluations to the class. This normally happened at the end of the making and testing. However, there were a few variations between the three units and between settings as well. The evaluation sheets for the three units for the English settings are reproduced in Appendix D.

Table 4.7: Evaluation schedules in the 3 settings for the 3 units indicating the different configurations of evaluation.

Setting	Own or other's	Bag	Windmill	Puppetry
Urban Marathi	Own Other's	Student Group evaluates another group	Group Group evaluates all others'	Group Group evaluates all others'
Rural Marathi	Own Other's	Student Group evaluates another group	Group Student evaluates all others'	Student Group evaluates all others'
Urban English	Own Other's	Student Group evaluates another group	Group Group evaluates all others'	Group Group evaluates all others'

Bag-making: The evaluation sheets provided to every student of the group had some questions that required him/her to rate their own group's bags on aesthetics, strength, durability and functionality. A 3-point Likert-type scale was used for the purpose. Besides, the sheet had a few open-ended questions pertaining to the cost and possible uses of their bags, and suggestions for design modifications, and whether and how the various design and make activities had helped them. An interesting question asked them to estimate the time required to make the same bag again. This evaluation sheet that individual students used to evaluate the group's own bag was different from the one that each group was given to evaluate one other group's bag. The latter had fewer questions. For instance, while evaluating the bag of his/her own group, the student had to reflect on how closely the finished product resembled their design, focusing student's attention on the process of going from designing (conceptualization) to product (actualization).

Windmill model: This was the only one among the three units developed was a model, and not the final technological artefact which helped *to solve problems and to enhance control over the natural and made environment in an endeavour to improve the human condition* or *to satisfy human needs and wants* (ITEA 2007). The windmill model was still evaluated on several parameters, as was the bag.

The evaluation sheets in windmill model unit had questions that were similar in format to those in the bag-making unit. In this case, whole groups evaluated their own products as well as the products of all other groups. However, only in the Rural Marathi setting, each student evaluated all the other groups' products (5 in all). A copy of the evaluation sheets used by groups (or the student in rural Marathi) to rate their own and another group's product are given in Appendix D.

To test the working of the windmill model under controlled conditions, an experimental set-up was devised consisting of a wind blower (a modified vacuum cleaner) set at constant wind speed and a template with angle markings. The following four parameters had to be noted:

- Distance of the model from the wind source
- Angle subtended by the model face with the line from the wind source to its location
- Weight loaded on the vane shaft
- Number of rotations of the vanes per minute

The model with a certain weight loading its vane shaft had to be placed sequentially at different marked distances from the constant wind source. At each distance, the orientation was varied over 180 degrees in steps of 30 degrees. At each orientation, the weights were varied up to a maximum of 30g. The number of rotations of the windmill blades was measured under each condition and students noted the values.

Group members took turns to note the conditions under which their group's model worked best and its maximum efficiency in terms of the maximum weight it could lift, the orientation in which it did so, and the rate at which it lifted the weight. When a model failed, the group set about redesigning some of the components with the help of peers and researchers.

After the evaluation was communicated to the class, researchers discussed with the students their own preparations for the unit, including researchers' own failed attempts. This aspect was included to give students a sense of being a part of a learning process that was equally challenging for researchers as well. It also encouraged students to openly discuss their own problems.

Puppetry: The puppetry unit involved evaluation of individual puppets after making. On the same lines as in the two earlier units, the evaluation of puppets involved each group filling out a semi-structured evaluation sheet assessing their puppet and another sheet for each of the five other puppets made by other groups. Again, as in the case of the windmill model, the rural Marathi students individually evaluated their group's puppet and as a group evaluated the puppets of other groups. After the evaluation, each group had to communicate to the rest of the class the details of making as well as their evaluation.

Questions in the sheet asked each groups to rate every puppet on ease of handling, movements of joints (number of movable parts), overall neatness and resemblance to the character in the story. Open-ended questions included suggestions for improving their puppet, differences between the design and actual puppet, and its estimated cost. Groups had to communicate their evaluations to the class. Students were encouraged to exchange ideas, ask questions and give constructive feedback.

An evaluation schedule was evolved to suit the product in the unit and the setting. This generated a lot of evaluation data reflecting student's progress in assessing products and their own strengths and weaknesses.

Collective sharing between settings

After the trials of the 3 D&T units in the three socio-cultural settings, students from the three settings were brought together for a sharing of their experiences of all the three units. A display of the artefacts made by the students in the three socio-cultural settings were arranged. Video recordings of the three puppet shows were played for the audience. This was an opportunity for students to learn about the existence of educational settings different from their own. This also helped them appreciate the variety in creative visualisation of the problem solution in the form of functional artefacts designed by students to use different resources, tools and skill sets. Student feedback was sought through a semi-structured format given in Appedix E.

4.3.8 Classroom interactions

The 15 hours of interaction for a unit happened over 3 to 5 days, which varied with the setting and unit. For the students from Urban schools, the classroom was one of the rooms – a lecture room or a laboratory – in the researchers' institute. In the case of tribal students, trials were conducted in a classroom in their own school over an entire school day and were hence completed in fewer days. The units were presented in the same sequence, but at different times for the three settings. The schedule of the trials of the 3 units conducted in the three settings is given in Table 4.5 of Section 4.3.5.

Interactions are best among people who are familiar with each other. The familiarisation process between the students and researchers was initiated by students being requested to fill a sheet giving information about their personal details. Besides name, school name, date of birth and age, this included information on mother's and father's occupations, performance (percentage of marks) in the most recent school examination, school subjects that were favoured and disliked, and their out-of-school activities. For the third (Urban English) setting, the information sheet included a question on their hobbies, especially whether they had made/ built/ constructed toy, etc. The final information sheet used is reproduced in Appendix B.

A number of steps were taken to enable better communication between students and teacher/researchers. Attempts were made to increase familiarity of all with the physical environment in which trials were carried; the urban students in the researchers' institute and the researchers in the rural village. Students were allowed to use the languages of their choice during both formal as well as informal communication. Familiarisation sessions among the Rural Marathi students included playing different kinds of games such as cricket and popular village games as *thikari*, *kho-kho*. There were attempts to improve students' presentations and encourage them to recount their experiences and ideas.

Gender aspects

One of the important aspects of the development as well as the trials of the units was the gender variable. It had an effect on the choice of units and the selection of the sample, and was incorporated in the the formation of activity teams and classroom interactions. The role of gender aspects in the development and trials of the units is briefly discussed below.

Choice of units: The tasks within each unit had a careful mix of activities like sewing, cutting, etc. that are traditionally associated with girls and activities like handling hammers, hacksaw, etc. that are considered "boys' stuff". Thus, students could get an experience of both the kinds of activities. Such an approach may help remove some of the traditional sex-role stereotypes prevalent in our society.

Choice of sample: It was arranged with the school in each setting to have an equal number of girls and boys participating in the trials.

Class organisation: Students worked on the design and make activities in groups. To enable us to study the effect of gender composition on the dynamics of the group and its work, three different kinds of groups were formed: two groups of girls, two groups of boys and two mixed sex groups. Asymmetry in the number of individuals in the mixed sex groups was avoided as far as possible. Subject to the availability of video cameras the dynamics within one single sex group and one mixed sex group was recorded.

Classroom interactions: The literature reveals that there are fewer girls than boys in technology education classrooms. This is also the case in India where we see around us, fewer girls opting for trades, technical and engineering courses. The researchers in this study made conscious efforts in a variety of ways being discussed here to encourage both girls and boys to participate equally in all the activities.

Language used: A deliberate attempt was made to use a gender-fair and gender sensitive language, like referring to 'human' and not 'man'. Even the examples used in a story for contextualising the windmill problem had a balance of characters representing both sexes. Sexist remarks were actively discouraged in class by engaging in sensitizing discussions.

Situations for articulation: Researchers built into the units situations where both girls and boys had to express themselves, be involved in discussions, asking questions and clearing doubts. Female students were encouraged to take leading roles in groups and to suggest modifications.

Handling tools and resources: Both girls and boys were encouraged to handle all kinds of tools, under supervision. Girls, who readily worked with tools inspired others. Coincidentally, the main researchers in the study included a male and a female. Conscious efforts were made to ensure that all tools were demonstrated by both, including handling of research tools like the recorders and video cameras.

Explicit discussion on gender inclusivity: Consideration of gender issues was made explicit when these were used as criteria in decision making wherever possible. Most opportunities were afforded in the puppetry unit: in choice of stories, proportion of female characters, in the actions and roles of females in the story, choice of the puppet to be made by a group, etc.

Thus, the researchers made conscious efforts toward developing a gender-fair set of units and having gender-sensitive classroom interactions with explicit references to gender fairness as part of the interactions. It was hoped that this would sensitize students to gender issues and and set an example for them to follow.

4.3.9 Classroom resources

The conduct of a D&T unit requires materials, tools and informational resources. Often school activities like art and craft call for such materials and tools. These may be available in a few schools. However, most schools do not have these materials and require students to bring them. Some of the material resources can come from the common waste - rags, bottles, paper, beads and coloured strings. Others may be inexpensive and easily available in the market. Tool sharing is encouraged in the making activity and common tools in house or school maintenance and repair can be used. Some investment on materials like cardboard sheets, decorative paper and wood batons is needed. School textbooks of different subjects and at different levels can be used as sources of information for motivation and investigation. The resources planned for and used in the development of the three units are summarised below.

Information sources: These may be print sources like pictures, photographs, line drawings, etc. available in school textbooks, reference books, children's magazines, newspaper articles, etc. Other animated information in the form of animated clips and videos are available on the internet or stored on CDs to be played on computers. A visit to relevant outdoors, an event or a location can also provide authentic and motivating experience; e.g. puppet-show, an industrial workplace or a museum.

Models and other artefacts: Easily available models and examples of familiar artefacts similar to the one needed to solve problem may be brought to the classroom for students to handle and familiarise.

Schedule and plan of activities: Thoughtful preparation of lesson plans, including a sequence of activities with flexibility to introduce teaching-learning sessions where needed helps in the smooth conduct of the units. Activities within a unit are organised into coherent chunks of one or more hours that could be spread across the available days. A day-wise schedule (lesson plan) giving the details of activities and the tentative time for each activity was chalked out. Such a plan for the unit on windmill model along with the details for the second day is given in Appendix C. Structure of units allows for individual creativity as well as group work and team effort. Individual and collaborative activities were separately noted in the plan.

Materials and tools: Besides a blackboard and chalk, materials required include stationery (paper, pencils, geometric instruments, markers), cutters, scissors, sewing tools, vice, clamps, hacksaws and other simple carpentry tools like hand drills, hammers and nails, materials like craft paper and cardboard, gelatine, pieces of cloth, beads, jewellery and other used accessories. All kinds of waste materials like used water bottles, ball-pen refills, empty thread reels, empty cardboard boxes and cans are useful to have around during the making phase of any D&T unit.

Issues of availability and handling also needed to be considered for these tools and resources. For example, a tool or any other resource unavailable to rural students should be first made accessible and known to rural students to ensure its proper utility. Enough scope for interaction with the material environment around should be built into the activities. Safety measures and economic use of resources should be conveyed through interaction with students so that it becomes integral to the work culture.

Structuring the output for assessment: Tangible outputs in each phase of the unit were also planned. Each unit included tasks to be done by individual students, through collaboration within smaller groups, and collectively by the class. The several kinds of paper-pencil productions generated, besides the products for assessment and analysis purposes. The research required audio-visual data as well.

Students comfort during their interactions with materials or people (researchers) was facilitated through activity sessions prior to the trials of the units. These initial sessions engaged students in drawing and communication activities, informal (e.g. play) activities and involved students' interaction with the audio-visual aids. Through these activities, students became used to the audio-video equipment as well as with the materials and people around, which then became a non-interfering background.

4.3.10 Evaluation and assessment issues

Though student assessment was not a primary concern of this research, the development and trials of the D&T units integrated peer evaluation strategies. Students evaluated their own group's artefact and other groups' artefacts as discussed in subsection 4.3.7. The students also maintained a group portfolio for each unit containing the productions of each member, which can help in assessing the performance and progress of each student. The portfolio, the product and the formal communication by groups had scope for formative and summative assessments of students' work by peers as well as by researchers (teachers). However, this was not a part of the present study.

4.4 Data sources

Data garnered in the trials of the three D&T units included paper-pencil productions which were part of the group portfolio, the finished products, audio-visual records of students' activities, researchers' observations, notes and logs. These are briefly described below.

Student productions: The primary source of data was students' paper-pencil productions. Students wrote the name of their group and, in case of an individual activity, indicated their name on every sheet they used and filed them in chronological order in their group portfolio. The productions in a portfolio as indicated in Figure 4.3 included the following:

- list of group members' names and information about their class, school, and interests
- Group members' descriptions, poems and stories
- Worksheets, such as activity sheets on body joints, filled by the group or each of its members
- Design productions in different phases of conceptualisation and articulation of design, in the form of exploratory sketches, technical drawings and procedural maps. Design explorations and listing of qualities were individual or group productions in different settings for different units as indicated in Table 4.8. The technical drawings and procedural maps were group productions in all settings for all units.

Table 4.8: Participation as individuals or groups in design exploration in the different samples for different units

Unit	**Setting/(s)**	**Explorations in groups/individual**
Bag-making	Urban Marathi, Rural Marathi	Group
Bag-making	Urban English	Individual
Windmill model	All settings	Groups
Puppetry	All settings	Individual

- Evaluation sheets recording students' evaluation of the artefact made by their own group and by other groups

The portfolios served as a ready reference about the group constitution, and chronology of the member's activities for the researchers. For students, it was a record of their past actions.

Audio-visuals: Trials of the D&T unit were recorded using one or two video cameras and 2 or 3 audio recorders. Audio recorders were placed amid a group of students. If 2 video cameras were available, one scanned the whole class, while the other was placed to record the dynamics within one mixed sex group. If only one was available, the camera panned the class. Students worked in groups and there were many conversations in parallel, which we were not equipped to record in detail. Video records included all phases of the D&T trials, interesting student engagements like animated discussions, conflict situations, aspects of decision making, exploring tools, etc.

In the Rural Marathi setting, nonavailability of electricity posed a major problem for recording data both in terms of charging the equipment and lighting in the room. We had to constrain the use of our cameras to capture short spans of design and product communication and explicit instances of engagements.

Observations and logs: Besides generating the portfolios and audio-visual records, researchers took turns in noting their observations during the conduct of the trials in the classroom. They also reflected on these observations while filling the logs at the end of each day of the trials, including their comments and suggestions for refinement.

Finished artefacts: The designs and plans translate through the making activity into tangible products. Together they indicate the process of designing and making. Differences between the processes within the three units may indicate progression of each group, if the group members remained unchanged through the units.

The different sources of data on student engagement helped to triangulate some of the observations. Students' design productions and classroom observations were analysed using a broad framework generated for the purpose. The framework and the results of the analysis are summarised in the following chapter.

The overall exercise provided rich contexts of learning for the researchers in making judgements about aspects that needed to be incorporated in developing D&T units. The trials served an immediate context for testing and validating the suitability of ideas. The active mechanism by which ideas were adapted to meet the immediate needs helped gain insights into what should constitute the D&T unit and what would engage students.

4.5 Summary of development and trials

Development and classroom trials of the D&T units for Indian middle school students was itself a process of designing a D&T curriculum. The researchers were collaboratively engaged in this designing activity!

The process of development and trials of units has been an iterative one: insights gained from the trial of the first unit in the first setting helped in refining our lesson plans for the subsequent settings. The flow of discussion in this chapter has attempted to capture the dynamics that influenced the selection of units and the structure of each unit. The discussions of the three units in terms of the six aspects attempt to highlight our progress through the design of the units that can serve as a model for teaching design and technology at the middle school level. The development process shows how efforts were directed toward gender inclusivity and adaptations made to suit the rural and the urban contexts.

The development was guided by the idea of technology not as a prescribed set of activities but engagement in design problem-solving through a loosely structured sequence of tasks. The structuring of the units has evolved as a logical sequence of activities within a unit that could provide students with the conceptual and skill pre-requisites as and when needed. Communication among students and between students and researchers as well as collaboration at several levels of interaction among all participants were integrated into the design of the units.

Thus, the entire exercise demonstrated that learning is a dynamic process involving adaptation to the contexts and continuous refinement in order to account for the needs and demands of the situation. Making a unit an authentic learning experience calls for tremendous efforts on the part of the teachers in selecting design problem-solving situations, channelling the open-ended discussions, integrating and valuing diverse means of expressing and initiating critical discussions. All these make D&T education a dynamic and enriching experience for teachers and students alike.

Chapter 5

Analysing design and cognition in D&T units

During the development and trials of the three D&T education units discussed in the previous chapter, data was generated in the form of middle school students' design productions and researchers' observations of students. This chapter begins with an elaboration of the research objective of analysing the trials of D&T education units for content and pedagogic aspects in classroom observations, and for cognitive aspects in students' design productions. The framework for analysing the productions and observations evolved towards achieving the specific objectives of analysis. This is followed by the presentation of results and discussion of issues that pertain to design and cognition as seen in students' design productions.

5.1 Analysis objectives

The research questions that guided the analysis of students' design productions and researchers' classroom observations during the development and trials of the three D&T education units in three distinct socio-cultural settings are listed below.

- What do the classroom observations of the trials reveal about students' engagement during different activities within each of the three D&T units in the three settings?

- What do students' design productions reveal about their design ideas and their cognitive activities?
- How do the differences in the three units influence the nature of students' design productions?
- In what ways does the context, urban or rural, socio-economic and linguistic settings influence students' designs?
- What do the observations and productions indicate about students' evolution in the design and make activities through the three units and in the three settings?

These research questions guided the conceptualisation of data modes, and organisation and analysis of the data collected through several sources. The analysis has been guided by two broad frameworks: one for researchers' written record of classroom observations and another for studying students' cognition through their design productions. These are briefly described below.

Classroom observations: Written records of daily class activities - including those before the design phases, during and between the design phases, and during the making - were maintained by researchers in the form of logs. Researchers' observations and logs, even those that are supported by the audio-visual records are essentially interpretive, context-bound and subjective. They are researchers' immediate impressions of class activities, and include comments and suggestions for refining the units in subsequent trials. Analysis categories for these written records were generated based on the six aspects discussed in the last chapter and are discussed in Section 5.2.

Design productions: Students' design productions, on the other hand, are more direct evidences of the cognitive processes in the D&T units. They include students' exploratory sketches, technical drawings, and making plans in the form of procedural maps. Besides these, there were evaluation sheets filled by groups or each group member, and the finished product. While these productions are influenced by contexts, they can still be compared across contexts. They aid the understanding of how students' ideas evolved through the three units and over time. The framework for analysis of design productions is described in Section 5.3.

Other written productions by students: The unit trials also generated productions by students other than design productions: writings of prose and poetry during the motivation and investigation phases, and activity sheets in teaching-learning sessions (e.g. learning about joints, technical drawings exposure, designing a postage stamp). These will be discussed along with the classroom observations.

The following two sections give the frameworks that were evolved for analysing observations and students' design productions.

5.2 Framework for analysing classroom observations

Categories, which were evolved to analyse the written records of classroom observations were guided by the six aspects discussed in the previous chapter, viz., influence of students' perceptions of technology, content of D&T units, cognition and technology education, teaching design and technology in schools, classroom interactions and classroom resources, and evaluation issues. These aspects and the categories within each, along with an illustrative example of observation record are listed in Table 5.1.

Observations that have occurred during the different phases of designing and those that support the deductions based on design productions will be discussed in the context of design production analysis in Section 5.5. Observations of students' making the artefact will be discussed in Section 5.7 on making and cognition. Besides, aspects of resource use, cognitive aspects and evaluation of products by students were seen largely in the context of design productions and making and hence will be reported in the respective sections. The framework for analysing design productions follows.

5.3 Framework for analysis of design productions

The design productions included *sketches* generated by students during their exploration of design, *technical drawings* of the artefact conceived by a group and a

Table 5.1: Framework for analysing classroom observations

Category	Description	An example
Students' perceptions and design explorations	• whether ideas shaped by perception of material properties, purpose or aesthetics • stereotypes of locales and people	Role of stereotypes of physical looks, region and religion influenced character sketch
Content knowledge and skills	• evidences of students' prior knowledge and skills • discussion of structure-function relations • language use and meaning making • problems and discussions on estimation and measurement	Guesses for an English name for a windmill
Teaching-learning and classroom interactions	• specific teaching-learning events planned • classroom interactions: group dynamics, conflicts and resolution, students' engagement in activities of estimating, measuring, etc.	Human body joints and movements it affords
Resource use	• materials and tools that students ask for, explored and used when made available	Realising cardpaper as appropriate material for making bag
Cognition aspects	• reasoning, justification, negotiation, evidence of visualisation and evidences of qualitative thinking	Use of graphical symbols to discuss assemblies
Students' discussion of evaluation	• students' comments on procedures, design productions and each other's products	Expressing the desire to make changes in design

step-by-step detail of the process of anticipated making and assembly, which is referred to as *procedural map*. The procedural map includes a textual description with an accompanying illustration of each step.

In each D&T unit, groups of students interacted with each other, and negotiated ideas. While doing so they constructed mental representations, externalised them in the form of design productions to be shared and manipulated by the group. Besides serving as an aid in their design, their representations and design productions indicated to us students' thoughts during the design process. The depictions showed how students selected and structured the information available to them. However, these manipulations are limited by the nature of depiction of a 3-D object on 2-D paper and students' graphicacy skills (Tversky 2002). Despite these limitations, the design productions in the D&T units from three socio-cultural settings were a window to the cognitive activity of the participating naïve designers.

Guided by theories on the process of design and visuospatial thinking, a framework was generated to analyse students' design productions. These students' productions were characterised in terms of features indicative of cognition as well as in terms of socio-cultural differences. Evidences were noted in terms of the extent and nature of exploratory sketches, use of graphical skills in technical drawings and procedural maps, their reasoning and justifications and their problem solving strategies. The framework for analysis, in terms of emergent aspects of cognition and corresponding indicative features in students' design productions are summarised in Table 5.2.

The inferences about cognitive aspects using the paper-pencil productions are complimented by students' filled evaluation sheets, vignettes from audio-visual data and researchers' written records of classroom observations.

The design envisaged and conceptualised in design productions gets translated into a product in the making phase through the use of the necessary materials, tools and other resources. Making is not just a simple process of translation but involves reflective action and transformation of design ideas, and therefore has been referred to as redesigning. Thus, design pervades all phases of a D&T unit. Studying the nature of changes while going from designing to making an artefact may give clues to students' cognition. The nature of change can be inferred by comparing students' design productions, with the observations of the making activities obtained from vignettes, audio-visual data and researchers' logs, and the finished product. The term *finished product* refers to an artefact or a system of artefacts, achieved as a result of groups of students working in collaboration. Suggestions for modifications were encouraged during the evaluation though it may not be feasible to continue with the entire redesign process through another cycle for each unit.

We now know from the analysis of design productions, that students' ideas evolved

Table 5.2: Aspects of cognition and corresponding indicative features in students' design productions

	Aspects studied	Features of design productions observed
		Cognitive aspects of design
1	Influence of the nature of D&T unit on productions	• Complexity and familiarity of the product • Extent of design explorations in the three units
2	Use of representational strategies in design productions	• Perspectives and views • Strategies for depicting details: Use of X-ray drawings; selective abstractions; enlarged views
3	Visuospatial thinking in design productions	• Quantitative reasoning: Estimations and proportions • Assemblies, joints and reinforcements • Use of symmetry, tessellations and repetitions • Analogies in design
4	Knowledge and skills in depictions, writings and their organisation	• Students' writings in procedural maps • Materials and their diversity across the 3 units
		Evolution of design and sociocultural features
5	Progression within and across the D&T units	• Refinement of design ideas within a D&T unit • Progress of students' cognitive activities in design across the three D&T units
6	Socio-cultural features	• Extent of explorations in different settings • Depiction strategies in the 3 settings • Knowledge and organisation • Issues of stability, strength and longevity in designs • Collaborative interactions

from the early exploratory sketches through technical drawing to the multi-step plan of anticipated making or the procedural map made by each group. For a comparison with the making process and the finished product, the procedural map serves as a valuable marker for the following reasons: (i) It marks the end of design conceptualisation, (ii) It is indicative of students' preparation for making, and (iii) Gives a comprehensive account of anticipated making through the illustrations as well as verbal descriptions. Evidences of cognitive aspects in making and redesigning will be discussed in Section 5.7.

The following sections sequentially discuss the analysis of classroom observations and students' design productions using the two broad frameworks discussed.

5.4 Discussion of classroom observations

In the trials of the three units, students in all settings filed their paper-pencil productions chronologically in their group portfolio with guidance from researchers.

The development was through classroom trials, each trial incorporating the experiential learning of researchers from the earlier ones. Hence it becomes important to discuss the evidences in the same sequence as the trials of the units were conducted, viz; bag-making, windmill model and puppetry. The findings from classroom observations for students' perceptions and design explorations, content knowledge and skills, and teaching-learning and classroom interactions are discussed below.

5.4.1 Students' perceptions and their design explorations

It is well established that learning experiences that take into account students' ideas (perceptions) are likely to be more cognitively engaging and productive. The observations reported give evidences for the effect of students' perceptions on their evolving ideas.

Perceptions of materials and their properties

During the design exploration phase in each unit, a discussion was initiated among students about materials and properties. For instance, in the bag-making unit, rural students discussed the suitability of plastic as a material for bags. Recognising its harm to the environment resulted in the avoidance of plastics, which became a negotiated design constraint. The conversation between a researcher and students in a Rural Marathi setting, drawn from the researchers' logs indicates how students arrived at the constraint. It is to be noted that *pishvi* in colloquial speech connotes a cloth bag. The word is used with an adjective for different kinds of bags. For example, *plastic-chi pishvi* is used for a plastic bag.

(R = Researcher; Ss = Students; B = Boy; G = Girl; [ ] = content translated into English by the researcher)

R: People say that we should avoid using plastics, why do they say that?
Ss [after some time]: They create dirt, when it rains it goes with water and blocks the drains
R: What happens then?
Ss: It causes foul smell and gives rise to *keedas*[worms].
R: Imagine there are lots of plastic bags in your school compound and a cow comes and is eating grass. Along with grass it eats some plastic, what will happen?
G: *Aatadi la chitkel* [It will stick to the intestine].
R: What will happen then?
G: *Aatadi kharab hoeel* [The intestine will get spoiled].
R: What else can happen?
B: Cow will die.
R: Like this, many animals die. The plastic gets stuck in their throat. Now if we have to carry all these things, we will not carry plastic bags. Then what is the alternative?
Ss: *Pishvi* [cloth bag]

Class conversations on these issues when encouraged can develop students' sensitivity to the consequences of materials used in designing and making artefacts. Besides, such discussions situate the activities in real-life contexts that not only enhance learning, but also foster children's thinking about human and environmental consequences of their design (Hill 1998).

Influence of students' perceptions were also observed in the other two units. In the windmill unit, an urban Marathi group arrived at the suitability of using thin wooden sheets in making vanes for their windmill model design through discussions.

Perception of activities

Students' enthusiasm for making toys, paper artefacts and working with clay was evident in all settings. When they were given sheets of paper to make whatever they wished, they generated a variety of paper artefacts: winnowing pan, camera, boats, basket and paper planes. Figure 5.1 is a scanned image of the paper boats made by Urban Marathi students. The Rural Marathi students told researchers that they could make fruits and carts from clay. Urban English students also talked about making clay models. They also liked repairing toys and making them from waste materials like a computer carton, a material available in plenty in urban environments. Toy making as a leisure activity, interested students across the three settings. This observation is along the lines of our finding reported in our survey that majority of students from all socio-cultural settings, preferred making a toy rather than buying one from the market, as discussed in Section 3.7.1.

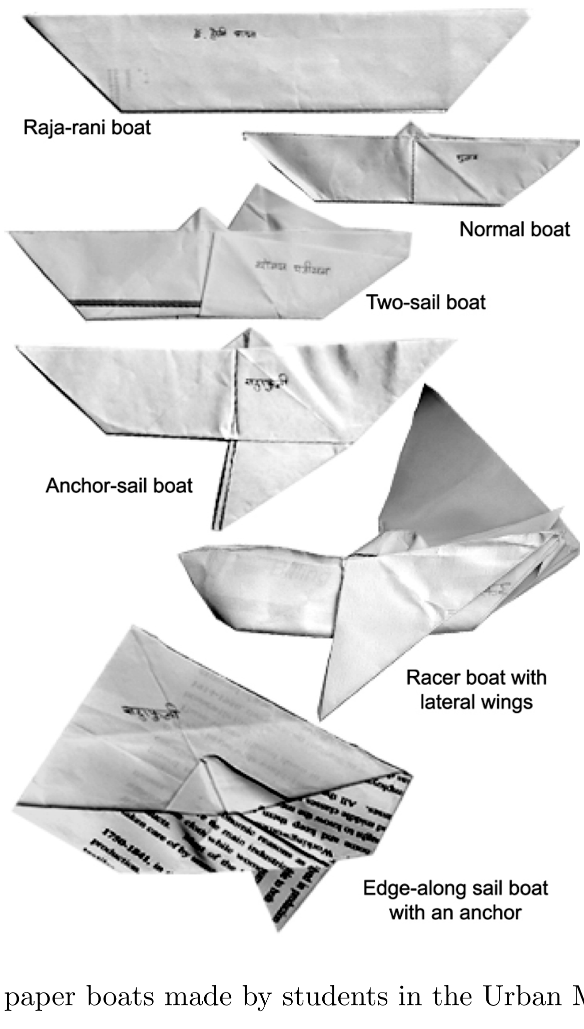


Fig. 5.1: A few paper boats made by students in the Urban Marathi settings.

In the puppetry unit, in all settings, students' consensus on the need for a story with a moral, but wanting to avoid the harshness of terminal violence forced them to modify the chosen story.

Perceived reasons for costing

While discussing issues of materials, students were asked to give estimates of quantities and cost. Students' estimates of cost of an artefact considered the bulk costs of materials used, as well as, the cost of tools. They did not consider reduced cost per use of reusables, nor did they include costs of time, labour, and marketing. When asked about the reasons for making cost estimations, students cited reasons associated with the monetary gains. The extract of Urban Marathi students reasons for making cost estimates drawn from the audio-visual data is given below.

> (S1, S2, S3 = Students)
> S1: To find out whether the cost [of a product] is high or low.
> S2: Since we are all making the same thing then why we spend more money on that. Because if that thing won't work properly then whatever money we had invested in that will be wasted.
> S3: To find out how much we can earn from that.

Social stereotypes of artefacts

Students' casual remarks reflected the commonly held stereotypes about region and religion in their discussions. This was especially seen in the unit on puppetry where students had to portray characteristics of a puppet.

The story chosen by the students in the Urban Marathi setting had the tribals, who protected the forest, a forest goddess (supernatural character), and a queen who lived in a palace with soldiers. The palace queen orders her soldiers to cut the trees of the forest, which invites the displeasure of the tribals and the forest goddess, who convince the queen in different ways to reverse her decision. Two of the groups in the Urban Marathi setting who made tribal characters visualised their puppets with stripes on their body and as those who communicate producing weird sounds. Similarly, students in the Rural Marathi setting felt that the demon, a supernatural character in their story, had to be portrayed with a huge physical stature, with a skull around its waist, unkempt hair, big nails and two huge horns on his head. These "primary generators" for them, symbolised the deadly image of a human-like monster! Primary generators are ideas that designers get hooked onto at a very early stage in design conceptualisation (Darke 1984).

An interesting discussion among a group of Urban English students revealed the influence of current affairs and students' stereotypes on visualisation of a female puppet character. The character discussed was that of an old widow in a story involving a family and dwarfs. While discussing the character of *Mary*, a widow, they first thought of a white saree but then realising that the story was set in London changed her dress to a skirt. While deciding how their character would look, one of the group members said that she should look like Sonia Gandhi (President of one of the major political parties in India), which led to an interesting conversation between a researcher and students. The following excerpt drawn from researchers' logs captures the interaction.

> (R = Researcher, Ss = Students, S1, S2, ... = Student; [ ] = comments by researcher to indicate the background information and situate the discussion)
> S1: She is an Italian, she is going to be our Prime minister. This is not good! [An issue in discussion on the legitimacy of a foreign born candidate to be nominated for the post of Indian Prime Minister]
> R: Then Advani [Leader of the major opposition party in India] is a Pakistani, since he was born there?
> S2: Our President [referring to then President, Dr. A. P. J. Kalam] is also a Pakistani then?
> R: How do you know that?
> S2: Because of his name.
> R: He was born in Rameswaram [a place in the southern tip of peninsular India].
> S2: But his name is like that.
> R: Even I am a Muslim, so am I also a Pakistani?
> Ss[from the group]: Tell us your name?

Social stereotypes are so strong and ingrained that adolescents tend to distinguish between people and make inferences about a region or a person's religion from their names.

Gendered aspects of technology played a role in the nature of objects chosen, its design and design activities taken up by individuals in a group. In the Urban English setting, a boys' group resisted making a female puppet. They felt that boys would find it difficult to make a female puppet, while girls could easily make puppets of either sex. Researchers initiated discussions with students to challenge their stereotypes and address their perceptions of technology.

5.4.2 Content: Students' knowledge and skills

Aspect of content involve the knowledge and skills that students bring to class and those that they acquire by being engaged in the units. It is also about the structure-function relations that students visualise, language and meaning making that happen during negotiations and their knowledge of and familiarity with making estimations and measurement.

The investigative phase was structured to make explicit the knowledge, skills and procedures that students bring to class. Students already had knowledge of functional aspects of familiar artefacts, skills of paper folding, clay moulding, toy repair, and could articulate features of a *good* product. On the other hand, all the phases of the D&T units aimed to help students acquire knowledge of concepts and procedures and a variety of linguistic (technical vocabulary), graphic and reasoning skills.

The concept of a *good* product reflected in their talk about the qualities of a bag such as it should be strong (should not tear easily), big enough to carry the given 5 books, waterproof, good to see, should have a handle and so easy to carry, should be soft, should be bad conductor (else would be hot in summer), light-weight, have a zip to prevent water from entering in, have pockets. Similarly, in the unit on puppetry, students applied criteria of goodness to stories, negotiated these criteria between groups during communication and used these to decide their group's story. The variety of descriptors used for a good story are summarised in Table 5.3.

Investigations enrich knowledge

Discussions about artefacts among researchers and students were based on students' use of terms to describe related objects which they had explored in different contexts.

Table 5.3: Descriptors of a "good" story by students in the three settings

Settings	**A "good" story should...**
Urban Marathi	have events - interesting, adventures; scenes - emotional, fearful, comedy; a moral
Rural Marathi	be easily understood; thought provoking; have a moral
Urban English	have different kinds of characters, interesting; coherence, humour, songs, climax or anticlimax; a moral; no killings

Students readily talked about objects based on what they had learned in school, from homes and their everyday experiences.

In the bag-making units, students first listed objects used for carrying things from one place to another and a list of several kinds of bags was generated (see Table 5.4). It is interesting to note that the range of objects for carrying things that students could think of. Insights about students' thinking can be noted through an analysis of the nature of objects rather than number. None of the objects listed by the Marathi medium students (urban and rural) had transport objects, they were merely of the container kind. Urban Marathi students listed school and material related objects while the list by rural students was more about kinds of bags based on the materials used. The urban English students could list a diverse set of possibilities such as container types, which were both traditional (*potli*, basket) and modern (suitcase) and served a range of purposes: bundling things as in a *potli*, boxes to carry animals. The objects listed also included carriers for goods (cargo) and even people using virtual devices.

Table 5.4: Objects used for carrying things from one place to another listed by students in the three settings in bag-making unit

Settings	**Objects**
Urban Marathi	School geometry box, School bag, Plastic bag, Cloth bag, *Chain packit* (zipped purse)
Rural Marathi	*Pishvi* (Cloth bag), *Potli* (Cloth bundle), *Thaila* (Bag in Marathi), Bag, Plastic bag
Urban English	Hands, *Potli*, Parcel, Box to carry animals, Suitcase, Baskets, Polythene bags, Ship, Goods train, Load carrying cranes, Trolley, Courier, Cargo, (Teleporting: "but we need a machine!")

Studying the kinds of bags listed yield insights into the spontaneous criteria that undermine their description of an object. The several kinds of bags listed by students in the three settings is given in Table 5.5. Analysis suggests that students in different settings used different criteria while listing object kinds. The urban Marathi students seemed to have used qualifiers such as human-body (shoulder, hand-bag), materials (paper, etc.), perceptual features (big, horizontal) and product experience (long-lasting) for listing the kinds. On the other hand, rural students used materials (tengus, terrycot), purpose (*daptar* (school bag), *thaili* (cloth bag), *peti*(trunk)) and the perceptual features (black plastic bag). The Urban English students listed bag types using qualifiers related to human-body parts, materials and purpose. The influence of language and settings is quite evident. Local experience of rural students who use a *peti* (trunk) for storing books comes through in their list. However, the purpose qualifier in the rural setting was quite different than in the urban setting: urban English students list had vanity bag, school bag and basket, while rural students listed objects associated with their local context such as *batwa*, *thaili*, *peti*.

Table 5.5: Kinds of bags listed by students in the three settings in bag-making unit

Settings	**Kinds of bags**
Urban Marathi	Shoulder bags, Hand bags, Paper bags, Plastic bags, Cloth bags, Big/small bags, Horizontal/vertical bags, Long-lasting bags
Rural Marathi	*Thaili* (bag with short handles), *Potli*, *Daptar* (School bag), *Tengus/Telus chi pishvi* (Jute bag), Cloth bag, “Terrycot” bag, Nylon thread bag, Plastic bag, Black plastic bags, Paper bag, *Batwa* (string purse), Packit (purse), *Peti* (Trunk)
Urban English	Shoulder bag, Back-pack, Hand, Polythene/Plastic bag, Vanity bag, Paper bag, Leather bag, School bag, Basket

Discussions that build on students’ prior knowledge, can motivate and engage students in investigations of related objects, especially when they were encouraged to look for different kinds and share their experiences with the class. For example, in the urban Marathi setting, a girl explained to the class details of a small bag called *aajichaa batwaa*, which literally translates to grandmother’s purse. She described in detail the purse and its use for keeping medicines. Several other instances of such motivated interaction were noted. A range of bag-designs which varied in materials, size, shape and purposes covering a spectrum of qualities in a familiar artefact thus got discussed.

In the unit on windmill model, the problem situation embedded in a story of two kids going to a fair, involved students talking about objects in a fair and the names for a pin-wheel. Two lists were generated, namely; for objects in a fair (see Table 5.6) and words used for a pinwheel (see Table 5.7).

Table 5.6: Objects in a fair listed by students in the three settings in unit on windmill model

Settings	**Objects in a fair**
Urban Marathi	Food, Different pots, Toys, *Akash palana* (Giant wheel)
Rural Marathi	Food, Car in photo-studio, Ball, Balloons, Bahuli (dolls), Masks, *Pungi* (Whistle), Books, Games like shooting balloons with gun
Urban English	Eatables, Magic shows, Toys, Dolls, Games, Giant wheels, Merry-go-round, Glassware, Handlooms, Monkey dance, Puppet shows, Clothes, Windmill or Firkis

Table 5.7: Labels for a pin-wheel by students in the three settings

Settings	**Labels for a pin-wheel**
Urban Marathi	*Hawai chakra* (Wind wheel), *Gol firanara pankha* (Round moving fan), *Firki* (a pin-wheel), *Ranga Chakra* (Coloured wheel), *Pawan chakki* (Wind-mill), *Panka* (Fan), *Kagadi Chakra* (Paper wheel), *Firate phool* (Moving flower), *Firanari chandani* (Moving stars)
Rural Marathi	*Pawan-chakki*, *Chakki* (Mill), *Chakri* (Wheel), *bhingri* (Spinning top), *Firki*
Urban English	*Hawachakri* in Bengali, Windmill, *Hawai-chakki* in Hindi, *Kataadi* in Malayalam, *Pawan-chakki* in Marathi, *Pambheri* in Punjabi, Firki

Students were shown a *firki* or a pinwheel and were asked names for it. They could come up with a list of names. It is interesting to note that most names listed by students in all settings derive from structurally related objects such as fan, mill, *chakra* (horizontal wheel). The labels used reflect the contribution of technology to vocabulary in a language, which also relates to the socio-cultural contexts in which technologies have been introduced. The urban Marathi students seemed to have constructed some of the names spontaneously. It has been reported that people coin novel *ad hoc* name expressions for entities, events, and situations that lack established names or in situations requiring to give name expressions. In such cases, people use existent lexical forms in novel combinations conveying the 'descriptive' property of referent rather than something practical and original (Thomas and Carroll 1984). The Urban English students who had diverse linguistic backgrounds contributed to the class activity by suggesting names for windmill in several regional languages.

In the motivation and investigation phase in the puppetry unit, students described their experiences of stage-shows, talked of all that was needed to put up a show, and words that mean puppets. The lists of stage-shows, the needs of a show and puppet meanings were generated from classroom observations and transcripts of video recordings. These are listed in Table 5.8.

The Urban English group showed the greatest variety in the nature of objects to carry things, objects in a fair and the kind of shows they had experienced. On the other hand, Urban Marathi group gave a number of words that mean the pin-wheel and similarly for puppets. All these point to the role of differential exposure of students to objects in different settings. Encouraging them to articulate and share their experiences of artefacts or events motivated students and helped initiate classroom interactions. Such interactions can serve as potential means for integrating diversity of languages and richness of experiences from diverse socio-cultural settings with school learning.

The words that students used for an artefact were not mere descriptives but also became a context for initiating a discussion. For example, the names suggested for a pinwheel triggered a class discussion on windmill and associated objects. Compare and contrast, as a strategy helped students investigate the structure and functional details of a windmill. The following example from Rural Marathi setting is a case in point. It was also noted that the Rural Marathi students, who otherwise were very shy and rarely talked, got actively engaged in discussion about windmills, much like the Urban students.

(R = Researcher; S,S1,S2,S3, . . . = Students, [ ] = Researcher's comments)
(Glossary of the closest equivalent English words: *Pawan-chakki* = Windmill, {*Bhingri* = Spinning top, *Chakki* = Mill, *Chakri* = Wheel, *Firki* = Pin-wheel)

R: Are pawanchakki, bhingri, chakki, chakri, firki the same?

Table 5.8: Artefacts listed by students in the three settings

	Kinds of stage-shows
Urban Marathi	School plays, Play Dahi-handi (means pyrmaid), Puppet-show, Ground natak, Acting
Rural Marathi	Orchestra, Circus, Drama
Urban English	Dances, Songs, Drama, Mono-acting, Mimicry, Magic shows, Puppet shows, Fancy dress, Animal shows, Circus, *Ram-leela* - an enactment of scenes from the *Ramayana* (a religious mythological epic) on open stage by local artistes during the *Dasshera* festival
	About stage-shows
Urban Marathi	Stage, Changing background images, Different dresses, Different sounds, Multiple roles by a person, Background music
Rural Marathi	Decorating the stage, Lights, Director, Narrator *Sutradhar*, Music, Instruments, Puppeteers, Prompters/background speakers
Urban English	Entertainment, Stage, Acting, Participants, Audience, Spotlight, Sound, Narrator, Music, Costumes (dresses), Make-up
	Puppets
Urban Marathi	*Kathputli* (Stick puppet), Dolls, *Bhatukalicha khel* (Traditional play of doll marriage in Maharashtra), *Haath bahuli* (Glove puppet), *Vyangya chitracha khel* (Cartoons), *Halnarya bahuliya* (String puppets), Battery dolls
Rural Marathi	Bahuli
Urban English	Glove, String, Finger, Stick, Robots

C: Yes

R: How does a Bhingri move?

S1: It moves round, but has a kadak dandi (a strong stick!)

R: What is the difference between a bhingri and the firki you have made?

S2: Firki moves with wind and bhingri moves by the movement of hands, bhingri moves aadvi [horizontal to the ground] while firki moves seedhi [vertical to the ground], bhingri does not have wings [blades] whereas firki has.

R: Are Chakri and firki same?...... Do you all think they [pawanchakki and firki] are the same?

S4: Pawanchakki has 2 patees [blades] and this firki has 4.
Pawanchakki is big while firki is small.
Blades of Pawanchakki are big, whereas that of firki are small
Speed of Pawanchakki is fast, whereas Firki is slow
S5: Pawanchakki has blades of iron, firki has of paper.
S6: In pawanchakki, the tower *daanda* [stick] is made of iron while in firki it is made of plastic.
S7: Pawanchakki is used for lifting water.

Students' understanding of the concept of two technological artefacts is seen through the criteria with which they distinguish the two related objects being discussed. Note that individuals willingly contribute and enrich peer knowledge with their own, thus enabling a lively learning atmosphere through a class discussion.

Structure-Function relations

Humans make sense of artefact world through understanding the structure-function relations. Making structure-function relations is fundamental to science education, for example, in the study of human body systems through the visual and verbal modes (Mathai and Ramadas 2006). Design content is based on making such relations about an imagined artefact.

Connect between structure and function can become explicit through handling of objects. While handling a pinwheel, students in the Urban Marathi settings made interesting statements about its structure and function, which contributed to the collective knowledge of the class about the artefact. The following extract from audio-visual data is one such example:

(MX1, MX2 = Mixed sex groups; G1, G2 = Girls' group)
MX1: Paper has been cut and stuck to the straw with the help of pin.
MX2: Straw is providing support to that fan.
G1: It is made up of paper, it is much lighter and can rotate with the air.
G2: Paper was cut and folded in such way that air can pass through so that it can rotate.

Students' struggle to reconcile structure and perceived function came up in many discussions. An instance is that of students in the urban English setting. They chose a story for puppetry about a mother, her two daughters and three dwarfs, who were supposed to be the three months of the year: *January*, *May* and *December*. For the mixed sex group that chose to make a dwarf named *January*, the problem was how to make the puppet to represent a dwarf character distinctly as a month. They were urged by researchers to extend their imagination and think in creative ways. Evidences for conscious efforts towards making structure-function association can be noticed in the focused discussion which included age, season, etc. among the other important aspects discussed in the group.

One of the ideas was that of the puppet's age. While they agreed that their *January* puppet had to be 2004 years old (the current year), they wondered about how to show that age. One of the members suggested that 82 years was all they could show - an interesting concept of how age is perceived. The age of the dwarfs was a recurrent discussion in this setting. During a communication session, a student wondered if ever months of a year could be depicted for age. Human age is counted in years, with each year comprising of 12 months. Therefore they argued, a month depicted as a human-like character invariably had to be shown very old! In fact, age was one of the key discussions in the puppetry unit in all settings.

The group (*Team Science*, an all boys group) that chose *May* as the character saw season as the distinctive feature of this month. These students from the hot and sultry city of Mumbai wanted to show *May* as the sun, in shining yellow. Besides, the three groups who chose the three dwarfs consulted each other on questions about how the three months should look, and the relation between the dwarfs – whether they were brothers or friends. Hence, it was decided that the three dwarfs would wear black dress and were friends. Thus, students' perceptions played a role in deciding parameters like visual depiction of months as live characters, age, dress and the relation between the dwarfs. Similarly, urban Marathi students perceived *adivasis* (tribals) as protectors of the forest and conceptualised a tribal character with a spear in hand. This structural attribute prevailed over their own description that the character was a soft-spoken individual. One common alternate conception that students had was that the windmill produces wind as does a fan. Perhaps, this conception is derived from the structural similarity of a windmill to a fan. Students in all units and in all settings saw visuals of related artefacts and experienced for themselves the material details, design and functioning of artefacts by handling them.

Language use and meaning making

Students' ability to make subtle distinction in word meanings got revealed in their select use of the word. Marathi medium students used *akruti* for diagram or an illustration and *chitra* for a picture.

Windmill is an artefact known to students only through visuals in their textbooks and descriptions of it in the newspapers and other media. However, students in the Urban Marathi medium did not know the English name "Windmill". When visuals of windmill were shown to them in the familiarising exercise, they made clever guesses of a name, often stretching their existing linguistic ability to accommodate new vocabulary. The following discussion drawn from researchers' log, is the interaction facilitated by a researcher with Urban Marathi students in the unit on windmill model.

> (R = Researcher; S1,S2 = Students; Ss = Many students together; [] = text in brackets are comments by researcher)
> R: What would you call this (pointing to a picture) in English?
> S1: *Dalnyache kaam karte* [It does grinding work, so . . .] (thinks for a while and replies). *Dalan* [Grind] is *pissing* [meant grinding] in English and it is a *yantra* [a machine], so it should be called a *Pissing Machine.*
> (The Marathi medium students translated *pisne* (to grind) in Marathi to *pissing* comparable to grinding in English.)
> R: These objects [referring to visuals of windmill] run with the help of . . .
> Ss: Wind (kept guessing).
> R: Wind in Marathi is . . .
> S: *Hava.*
> R: What else is it called in Marathi?
> S2: *Vara*
> R: what else?
> S3: *Pawan*
> R: And what work does it do?

S3: It grinds.
S4: What is a *chakki* called in English?
R: It's called a mill.
S4: Pawan-chakki, Windmill
R: So the Pawnchakki is called a Windmill, a mill run by the wind.

The Urban English described the meaning of a ventriloquist. The class discussion about a ventriloquist and its role is captured in following vignette, which is drawn from researchers' log and the audio-visuals.

(R = Researcher, Ss = Many students together, S1, S2, ... = Students)
R: What kind of movements and expressions can a puppet depict?
Ss: A puppet can walk, eat, leap, fight, talk ...
S1: How can a puppet talk? It cannot move its mouth.
R: Didn't you ever see a puppet talking? Has anyone of you seen a puppet talking in a puppet show?
Ss: Yes
R: Where have you seen a talking puppet?
S1: Teacher, I had seen it on TV in a show on NDTV channel
(S2 talks about a puppet show where a man comes on the stage with a puppet and he says something and at the same time moves the puppet and makes voices.)
S3 points out that such a person is called a ventriloquist. He further explains the meaning of the word.

Discussions in technology education units thus afford opportunities for use of specific words and widening the general vocabulary of class through peer learning.

Problems in estimation and measurement

Students had difficulties in estimating sizes. Their problem increased when they had to make estimates of materials needed for making artefacts, especially in the case of the first unit on bag-making. For instance, the Urban Marathi students were found to be uncomfortable with the use of scales and units (cm, inches). However, they knew that 100cm was equal to 1 meter. They could not estimate the amount of material that they would need to make their bag that they had planned.

Students often did not take into account the margins of cloth needed for folding and sewing. The problem was brought to the notice of students, some of whom modified their design appropriately, while others resisted change and went ahead with their making. They had problems in putting their hands in the glove, while handling their puppets. Students acknowledged this fact in their evaluation of puppets and made this point explicit in their communication of finished and evaluated products.

5.4.3 Teaching-learning aspects and classroom interactions

The teaching-learning process involved a combination of teaching strategies which were used as per the needs of the class to teach concepts and skills. Exposure to a range of similar artefacts was a strategy used to encourage students to make structure-function connections and draw their attention to subtleties of design. The units were structured to encourage contextual skill development. Activity sheets helped students exercise some of the skills and ideas that they had acquired. Explicit teaching activities and exercises provided students the knowledge base to explore and enquire. Scaffolding was provided by the researcher/teacher, who at times challenged students' ideas so as to encourage them to think and articulate their arguments.

A session on measurements and an exposure to conventions of technical drawings was structured to help students represent better the various components of a designed object. Objects of various kinds like rectangular cardboard, wooden cubes were used. Students soon realised that it is easier to represent some objects in technical drawings than describing them in words. Other objects such as a photoframe, cylinders, round objects and their portfolio file's dimensions were also discussed. By this time students had gained an idea of using conventions and they could comfortably represent lengths and sizes in technical drawings using the conventions and addressed proportions in their representation. An example of a mug drawn using the language of (conventions in) technical drawings is depicted in Figure 5.2. Students in all settings used conventions in all their subsequent productions.

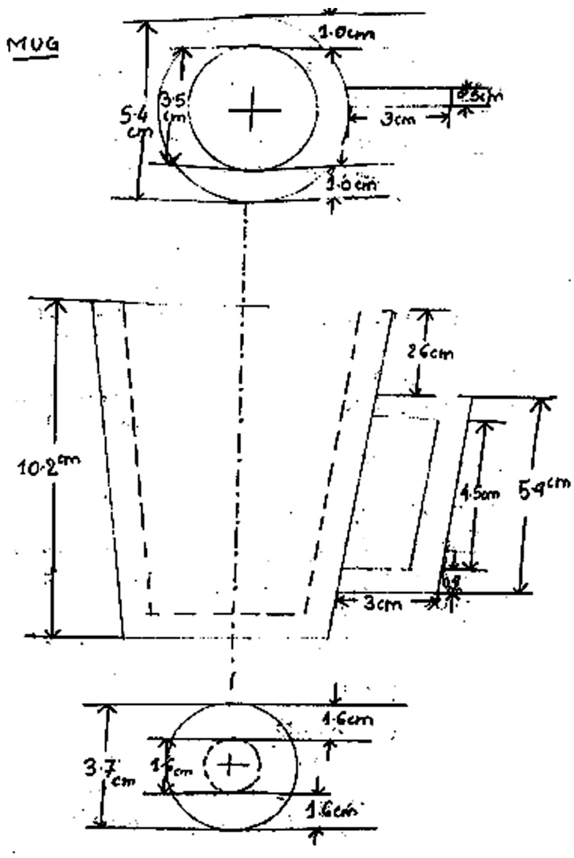


Fig. 5.2: A mug depicted by a female student in the Urban English sample using the conventions of technical drawings.

Visuals, animations and video clips were used to discuss models and working of artefacts and joints in the human body. Line drawings of human figures were used to initiate discussions on body proportions. Students explored their own body movements in groups and filled in a worksheet. An example of a filled worksheet from a girls' group in the Urban English settings is given in Figure 5.3.

In each unit, students handled related artefacts and explored a variety of designs. They handled different kinds of puppets (stick, finger, marionettes and glove) of their choice. They listed different actions (motion/movements) and emotions that were possible in the puppet that their group handled. Such an activity helped students explore a glove puppet in terms of the possible range of actions and expressions. They also wrote about the artefact they planned to make. Figure 5.4 depicts group discussion among students and the list generated by a girls' group in an Urban English setting.

How do your joints move? Try to move your joints and then put a tick (√) in only one box for each of the body joints

Body Joints	Forward/Backwards	Forward/Backwards & sideways	Circular/ All the way
Neck		✓	
Shoulder joint			✓
Elbow	✓		
Thumb (Hands)	✓		
Fingers of hands			✓
Wrist			✓
Waist			✓
Hip joint			✓
Knees		✓	
Ankle			✓
Toes			✓

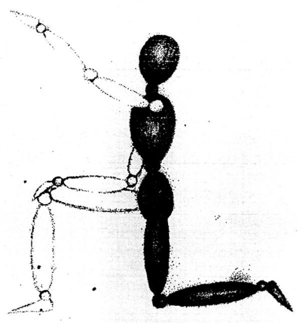


Fig. 5.3: Worksheet on exploration of body joints by a group in the English settings

Negotiations

Negotiation in the context of D&T units refers to the discussion between individuals in order to reach a consensus, and may include challenging the ideas, exchange of views and clarifications. Students negotiated the design problem context with the

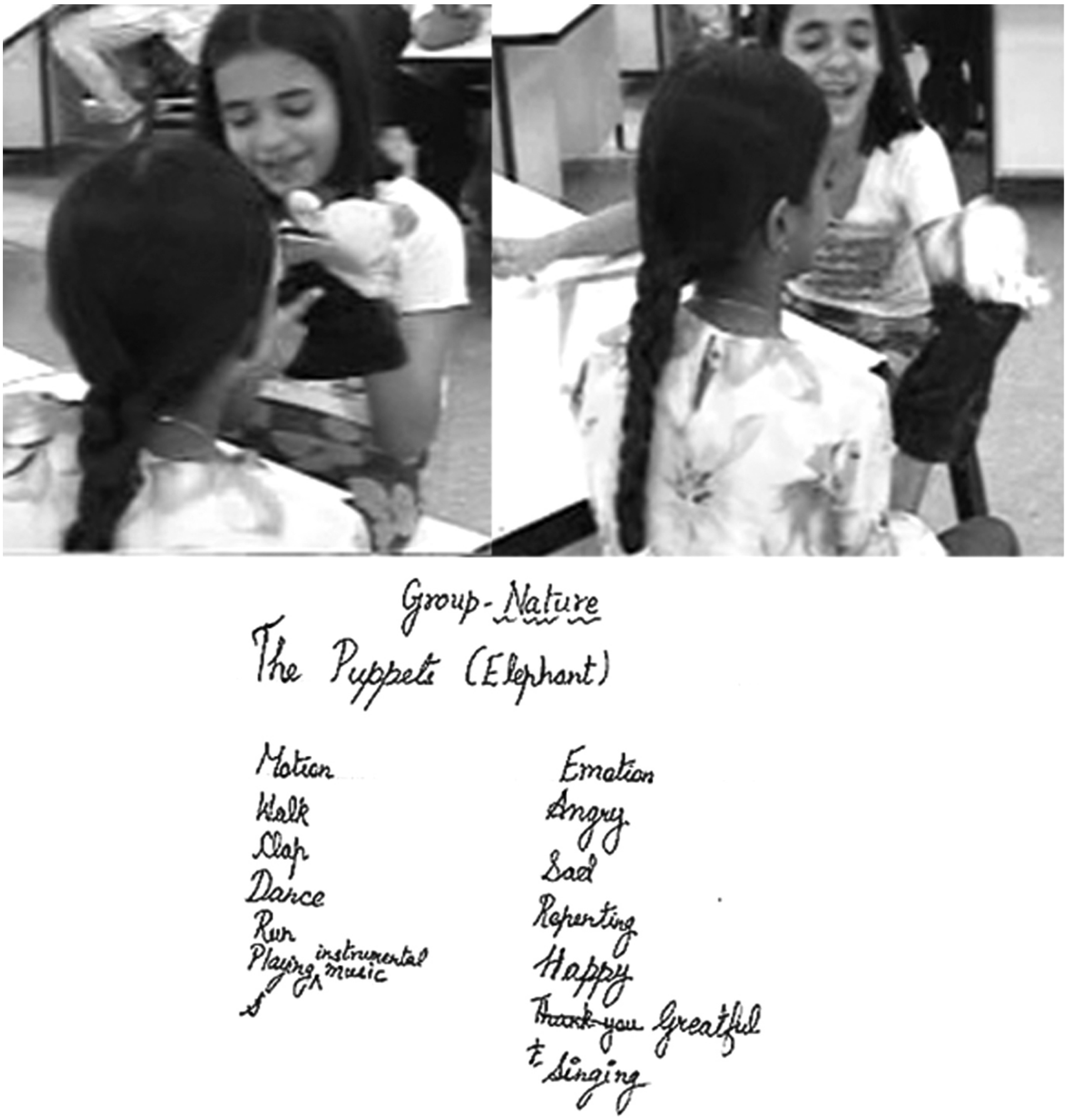


Fig. 5.4: (a) Actions (motion) and emotions of a glove puppet (an elephant) investigated by a girls' group in the Urban English setting; (b) Two frames showing joint exploration of the possible puppet movements by the group members.

researchers, and in a variety of situations among groups and between groups. Some situations for negotiations were also structured in the unit.

An event in the bag-making unit, where a girl student in the Urban English setting challenged the problem situation is presented below. The situation was: *How would you carry 5 books to a friend's place to study every evening for a month.* The negotiations that followed in the class, extracted from the researchers' logs, are reported below.

> (G1 = Girl; B1 = Boy, R = Researcher)
> G1: If I had to go everyday to friend's house, then I'd better keep the books at friend's place.
> B1: The next day you might find that the pages from the book are torn. So you cannot leave your books. Therefore, you need to carry them in a bag.
> R: You need to work further with the books so you would like to take books home and bring them back again.
> Other students gave alternatives like buying an extra set of books to be kept at friend's place.

Not having a relevant skill at times posed problems while conceptualising design ideas. For example, in a boys' group in the Urban Marathi setting, the members were divided in the choice of raw materials for the product to be designed. Two of the boys wanted their group's bag to be made of paper. A third boy wanted to make it of cloth. Almost spontaneously, the other members of the group wanted to know if he could sew. Thus, the knowledge of materials and skills affected the conceptualisation of design.

5.5 Cognitive aspects of students' design productions

> Each drawing is a laboratory in which to study – Edward de Bono (1972, p12)

Students worked in groups to design and make an artefact. They negotiated with the group members to choose a design alternative, decide on the details of components, materials and process of assembly. These negotiations were mediated by their mental representations externalised in the form of paper-pencil sketches and drawings, which we refer to as *design productions*. Though the representation of a 3-D conception on

2-D paper posed several problems to students, including the limits on the transformations of objects (Tversky 2002), the productions served to reveal how students selected and structured the information available to them. Thus the productions aided students' design process, as well as served to reveal to researchers the cognitive activity in the design practices of the participating naïve designers. The productions are analysed using the framework discussed in Section 5.2. Findings for the unit on windmill model making have been published (Khunyakari, Mehrotra, Chunawala and Natarajan 2007).

5.5.1 Influence of the nature of D&T unit on productions

The familiarity and complexity of the product conceived and designed is an important feature of the D&T unit. Through the design constraints and specifications they impose and influence the productions. Besides, the D&T unit also influences the productions through the prior knowledge of concepts, procedures and skills it requires of the students. All these influences operate during the conceptualization of the artefact. Students' prior knowledge of properties of materials, their exposure to tools and skills of tool use were operative less during the designing phases and more significantly influenced the making phase. The other influences on productions come from the socio-cultural settings of the students. Evidences for the connections between design productions and features of the D&T unit in the three settings are elaborated below.

Complexity and familiarity of product

Two major considerations during the choice of products for the D&T units were complexity of the artefact and the level of familiarity of the artefact among middle school students. The terms familiarity and complexity were discussed in Section 4.3.3. In general, the complexity of any product can vary independent of its familiarity as summarised in the matrix in Table 4.3.

The level of complexity and familiarity of the product varied in the three different D&T units. Familiarity was confirmed through students' communications and in the writings (descriptions of windmill, puppet). An artefact like the bag was considered a simple one as the structure and range of materials were known. On the other hand, even a component of windmill, such as the vane structure, has a large number of potential options for structure and materials. The windmill, an assembly of several components that functioned as one product, was the least familiar and most complex. A puppet character for a story could be visualised differently by members of a group. It afforded more options than a bag and fewer than some of the windmill components. Besides, the different products (puppets) had to be co-ordinated to produce a system (puppet show), involving unfamiliar and complex maneuvers and collaborations.

In the relatively simple unit on making a bag, the Marathi medium groups, who have not been exposed by us to technical drawings, still almost spontaneously made technical drawings. However, they had problems representing depth and did not indicate dimensions correctly. The situation with regard to making technical drawings improved in the later units and after exposure to a session on technical drawings. Students included more details in their technical drawings of a puppet. Whereas, for windmill model which involved a complex, assembled object, they spent more time on a windmill model.

The analysis of the design productions in the three prototypical D&T units revealed a dependence of the extent of explorations on the familiarity and complexity of the unit.

Extent of explorations in the three units

The number of design explorations made by students were studied. The explorations of urban students were well preserved but records of the explorations of rural students were far fewer. This is because the rural students used their resources sparingly, including the paper provided to them. They often erased and drew or wrote on the same sheet of paper. Though we have an account of erasures, these have not been included in the analysis.

Students made more sketches during the design of a less familiar and complex object like windmill, than while designing either a puppet or a bag. Average number of explorations per group for the three units is given in Table 5.14 (item 2). The number of explorations in the most complex windmill unit (18 per group), is greater than that in the puppetry unit (5), which in turn is greater than that in the bag-making unit (3). This follows the familiarity-complexity matrix.

The trends were similar across the three settings as seen in Table 5.9. This indicated that the extent of explorations increased with increasing complexity and unfamiliarity of a conceived product. It would follow that there should be more explorations while students attempted to depict imaginary characters. The chosen puppet stories in all settings involved at least one imaginary character like *rakshas* (demon), dwarf and *vanadevi* (forest goddess). It was, in fact, found that these imaginary characters were explored with more sketches than normal human characters. It is known that the first experiences of infants in drawing start with doodles and the earliest of the visually meaningful externalisations of pre-school children are the human forms (Goodnow 1977, Gardner 1980).

In comparison to complex machines like the windmill model, imaginary characters seemed easier to visualise and elicited less explorations. This is possibly because students across all settings had an exposure to folk-stories and popular local fantasies. The kind of imaginary character chosen by students from different settings was also indicative of their exposure to different kinds of stories.

Table 5.9: Total number of explorations and average per group in each setting for the three D&T units.

Setting	**Bag**	**Windmill model**	**Puppetry**	**Total**
Urban Marathi	26	144	38	208
No. of groups/ Avg. per group	6/4.33	7/20.57	6/6.33	19/10.95
Rural Marathi	06	0*	25	31
No. of groups/ Avg. per group	6/1	6/0*	6/4.17	12/2.58
Urban English	27	87	35	149
No. of groups/ Avg. per group	6/4.5	6/14.5	6/5.83	18/8.28
Total	59	231	98	388
No. of groups/ Avg. per group	18/3.28	13/17.77	18/5.44	49/17.92

Note: * = Not counted for total no. of groups and total average

Artefacts are made of one or more parts. Those that are made of more than one part can, in general be decomposed into its constituent parts. The number and kind of parts into which an artefact is decomposed may be guided by the aim of the analysis, which may be related to its structure, its mechanical function, aesthetic or social function, and so on. In terms of the structure, a bag may have two major sides, a base, width and handle; whereas for understanding its mechanical function, the bag may be decomposed into a container and a handle. A puppet is itself a component of the puppet show, a technological system. Complex or unfamiliar components and assembly of an artefact or system elicited greater exploratory sketches than simple ones. This was also seen in the design of the windmill model.

Students explored some components using a greater number of sketches. This may either indicate a need to ease the cognitive load of designing a complex part or union. It has been reported that design explorations ease the cognitive load of designing among professional designers (Bilda and Gero 2005). Alternately, the part may have held the students' aesthetic interest. The number of exploratory sketches observed in each setting for each part in the windmill model is given in Table 5.10. In the unit on windmill, the urban groups made more sketches for exploring vanes (87) than for the other components. The number of explorations in the windmill unit decreased progressively from vanes and their assembly, to tower, and then to assembly of tower and axle to vanes.

Table 5.10: The number of exploratory sketches observed in students' productions in urban settings listed by parts of designed products.

Number of exploratory sketches	**Urban Marathi**	**Urban English**	**Total**
Vane structure	65	22	87
Tower	17	13	30
Axle/Shaft	2	8	10
Assembled components	15	8	23
Near finished product	9	7	16
Ambiguous depictions	36	29	65
Total	144	87	231

Note: The rural Marathi groups erased their drawings and made new ones on the same paper and we have little access to their explorations, hence not included in the table.

Extent of explorations is valuable, but are explorations informative in all problem-solving contexts? In another study reported elsewhere, the extent of explorations in design contexts were observed to be greater than in contexts requiring translation of textual description to depictions based on problem cues (Khunyakari, Chunawala and Natarajan 2007). One of the challenges for students was to diagrammatically depict on paper the imagined 3-dimensional object. Students without relevant prior training or instruction, spontaneously used a variety of strategies to convey the nuances of their designs. Issues relevant to analysing such depictions are discussed below.

5.5.2 Use of representational strategies in design productions

Students used perspectives while sketching their design and drew the details with dimensions in their technical drawings and procedural map. They used their graphical skills and a variety of techniques to convey their design ideas. Their visualisation of the complex 3-D object space was evident in their 2-D depictions of components, assemblies and descriptions of actions for making. The depictions also gave indications of conflicts in representation and their resolution. They used a variety of modes of expression like gestures of hands while discussing structures and assemblies, and discussions to elaborate and reason about their design.

Perspectives and views

Perspective is a technique by which a 3-D object is projected onto a plane surface like paper. Students used diverse strategies for depicting their designs like the use of multiple perspectives, front or lateral views for depiction of objects. Students' choice of perspective(s) for their productions seemed to be dependent on the nature of the conceived artefacts and the details they wished to show. Students in the three settings tended to opt for a lateral view (profile) for depicting their windmill model, and a front view for their bag and puppet design.

Solso (2003) attributed canonic representations to be a result of our vast experiences of the object that get classified and stored as "idealized image" in our long term memory. Such mental images are activated for example in most urban people at the mention of a clock, book, cup, etc., which may get expressed in their productions. Possibly students' bag projections reflect the canonic representations of this object familiar in all the three settings. If the productions were merely canonic representations, one might expect to have similar bag designs from all groups within a setting. The English groups had designs of shoulder bags with long handles, while many of the

Marathi medium groups had hand-bags. Though the sketches triggered among the groups within each setting were nearly similar, these evolved through the designing phase into bags of a variety of materials and features. The variety of final products in comparison to their canonical-like sketches of their bag suggests that the limited graphicacy skills of students may have led to this. It may also be that being the first unit, students had not made a prior connection between design and the final product.

The puppets being depicted in a frontal view may have been because the puppets were humanoid characters, whose backs had fewer features. Besides, all character sketches differentiated puppets in terms of frontal features. In fact human recognition from the early infant stage is essentially based on frontal appearance. Infants are sensitive to shape and structure of the human face from birth, but not the human body (Slaughter, Stone and Reed 2004). The focus of students on the frontal appearance of their puppet was noted even in their explorations (see Figure 5.5).

Fig. 5.5: Exploratory sketches of a forest goddess by an urban Marathi group, showing emphasis on the frontal appearance.

Students showed varying levels of proficiency in using perspectives. They occasionally used techniques like single-point perspective and selective distortions to convey their designs. The Urban Marathi and Rural Marathi students, who had not been exposed to technical drawings before the design of their bag, had difficulty depicting all three dimensions of the bag. They managed to indicate any two dimensions in proportion – usually height and width – and distorted the third. They also had problems showing the location and spacing of handles. An example of such a problem in depiction of bag is shown in Figure 5.6. Historically, artists began to use perspective only around the 15th century. The system of perspectives was invented in Italy during the Renaissance to make pictures look more like the world around (Gombrich 1996). It is therefore understood that the use of a perspective technique is not a natural inclination, but comes from culture specific training.

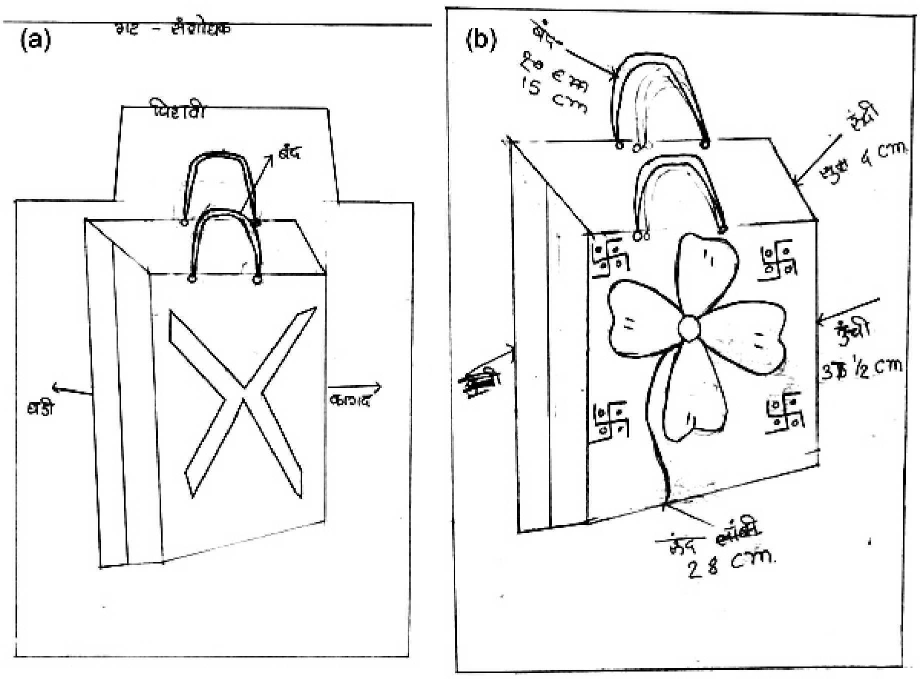


Fig. 5.6: Problem depicting a 3-D bag onto 2-D (paper) by an Urban Marathi group in (a) Final exploratory sketch and (b) Technical drawing. Also note the depiction of dimensions as labels.

Much of the graphicacy problems got addressed after students' exposure to technical drawings. Some depiction problems that continued may be because of the increasing complexity of depictions. A lateral perspective was seen in the unit on windmill model in almost all the groups. The multiplicity of components in different planes forced the students to use a view other than the frontal one. That way, they were able to occlude less of the assembly and reveal more details. This unit elicited multiple perspectives in the same drawing. For example, in the technical drawing of a Marathi group, the tower was represented using a one-point perspective, and the axle and the vane structure as 2-D views. One of the urban Marathi groups, had problems depicting a composite vane structure made of rectangular components in mutually perpendicular planes. Such problems may be resolved in three possible ways: (1) reducing the importance of one of the components (a dissonant element), (2) reinterpreting one or more of the elements, or (3) changing one of the dissonant elements (Solso 2003). In their drawings, one group of students opted for the last one, and changed the shape of one of the rectangular components to a flag shape and inserted it at an angle other than the perpendicular. This is indicated in Figure 5.7.

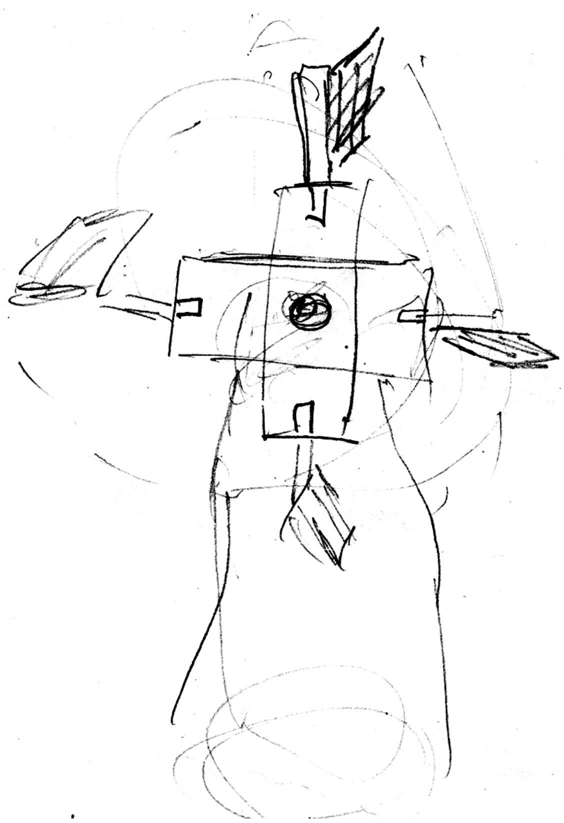


Fig. 5.7: A production exhibiting change of a perpendicular part of the vane component to a angular flag-like structure by students in a mixed group in the Urban Marathi setting. Also note the use of graphical symbols to denote motion of vanes and base of the tower.

The functional attributes of design, coupled with the unfamiliar complex nature of the object led to design productions of the windmill model, each of which was an artistic confluence of multiple strategies in a single depiction.

Strategies for depicting details

Students from all settings devised a variety of techniques to depict the product design, draw attention to components and detail them. This included using icons, x-ray diagrams, enlarged views, notations and symbols. Students who were naïve designers invented graphical symbols, like hazy lines, circles and over tracing, to depict components or motion.

Some groups while making their design of windmill models used hazy and discontinuous lines to suggest tentative poles and vanes. Such selective and specific use of graphical symbols has been reported in professional designer's sketches in studies on design and visual thinking processes (Cross 1982, Do and Gross 2001). Differences were noted in terms of the meaning of a symbol which changed with context: a curved line around a vane assembly was used to show motion, around a tower to show tentativeness in a component structure, or for isolation of one exploratory sketch from another.

The greatest diversity of graphical symbols (circular lines, hazy lines, etc.) was noticed in the unit on windmill. The design of a mechanical, non-manual (operated by wind) device like windmill afforded scope for generation and use of symbols, especially for depicting motion. According to Scaife and Rogers (1996), static diagrams represent products, while dynamic diagrams represent processes. The number of exploratory sketches depicting a static windmill was almost 9 times more than the sketches depicting a dynamic one (indicated by the use of motion symbols).

Groups of students across all settings were observed to have generated and used icons in their productions in all three units. There were icons of materials (glue-tube) and tools (hammer, scissors) in procedural maps and exploratory sketches. As in the case of graphical symbols, the number of icons in the windmill unit was more than those in the other D&T units.

Use of X-ray drawings: According to the literature on the developmental sequence in drawings, students above 9 years of age rarely use X-ray drawings (Anning 1997). However, students in our study tended to use such drawings in design depictions, especially those involving assembly of components. Windmill had components that involved assembly in occluded (unexposed) spaces. Hence, the

Table 5.11: Instances of X-ray in students' productions in the three units in the three settings

Setting	Bag	Windmill model	Puppetry	Total
Urban Marathi	04	07	02	13
Rural Marathi	05	15	01	21
Urban English	02	01	01	04
Total	11	23	4	38

X-ray drawings were used most in the unit on windmill (23), sparingly in the unit on bag (11) and were least in the unit on puppetry (04). X-ray drawing served to be a useful technique to solve a difficult problem. Table 5.11 gives a summary of the instances of X-ray drawings in students' productions in the three D&T units, in the three settings.

Selective abstractions: Groups in urban settings used the technique of selective abstraction, that is, reduced some components in a complex assembly to icons in order to facilitate elaboration of other aspects of the assembly. In the windmill unit, 2 (out of 12) urban groups represented the vanes as sticks while depicting the complex assembly of vanes, tower poles and the axle. In the puppetry unit, one of the groups depicted the spear as a stick with an arrow. Examples of the abstractions in students' drawings in the units on windmill model are shown in Figure 5.8.

Enlarged views: Students drew attention to features in their design productions and to highlight structural details or assembly of components, by means of enlarged views. An enlarged view is a valuable strategy for understanding components and their assembly in devices. An enlarged view is a blown-up or zoomed-in view of a part with an elaboration of details.

The largest number of enlarged views were seen in the windmill unit (15), (refer Table 5.14) than in the other two units, bag (2) and puppetry (0). The frequency of such views also differed between the three settings. These depictions were spontaneous productions of students without any formal instruction or training. A detailed study may give clues to the differential inclinations of students to include such views.

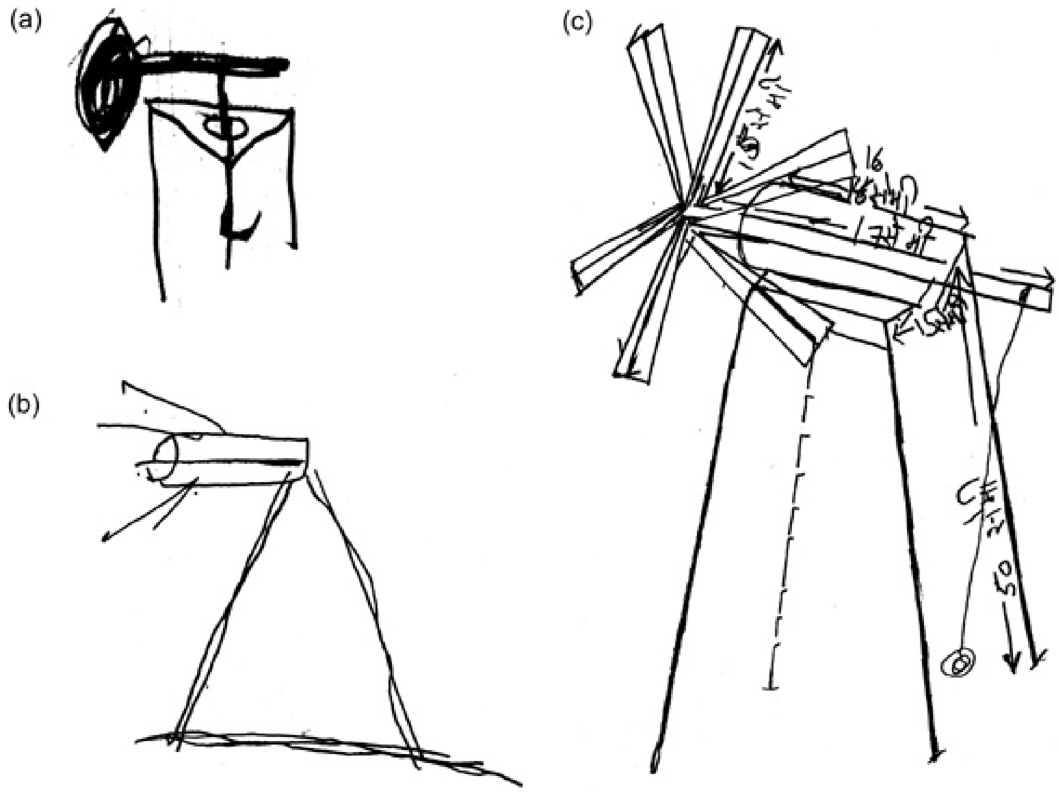


Fig. 5.8: Selective abstraction noted in students' productions of windmill model in different settings. Note the use of lateral views, selective abstraction of vanes (b) and tower poles as lines in drawing (b) and (c).

At times, students displayed creative ways of representing assemblies in their design productions. For example, one of the urban Marathi group showed the assembly of the axle by depicting it in the form of a mathematical equation with an aluminium nail, and a hollow cylinder and an addition sign on the left hand side of the expression (see Figure 5.9). This is one visual evidence of students making connections across disciplines and using them to their advantage. Such an illustration reiterates observations about diagrams as an arrangement of visual symbols standing for properties of the referent objects involved (Cheng, Lowe and Scaife 2001).

Summary of strategies used for design depictions

The nature of the units, students' conception of the products to be made in each unit and the settings influenced the strategies used by students as observed in their design productions. Differences were seen in students' choice of perspectives and the special

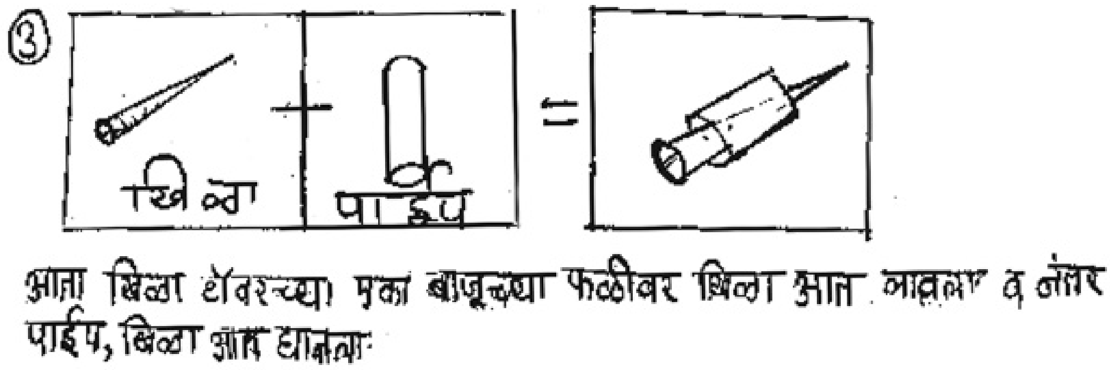


Fig. 5.9: A step in the procedural map of a girls' group in the Urban Marathi setting. The text translates as "Now the nail is [kept] on a wooden plank besides the tower and then the nail is adjusted inside[the pipe] and thereafter it was inserted in it

techniques they employed. Students spontaneously used a range of techniques like icons, graphical symbols, X-ray diagrams, enlarged views and selective abstraction, without prior training or instruction. Their choice of perspectives and techniques reflect the aspects that they wanted to highlight and communicate through their design productions. The observations raised interesting possibilities for the effectiveness of design productions if exposure and orientation to the tools of representation were provided to the students. The contexts of use of the techniques also indicated the nature of students' visuospatial reasoning and judgements made by them during design.

5.5.3 Visuo-spatial thinking in design productions

Students used a variety of modes to conceptualise and negotiate their ideas, as observed in the design productions and audio-visual data: peer talk, gestures, sketches, structural analogies, referents of existing concrete objects around them. Among student designers, gestures are known to assist and even prompt spatial thinking and development of images in the mind's eye (Athavankar 1999). The models and codes that designers' use rely heavily on graphic images, like diagrams, sketches and technical drawings, to aid internal thinking as well as to share design ideas (Cross 1982). Evidences for visuospatial reasoning were seen in all types of design productions. Technical drawings involve dimensioning the components and their parts, matching the dimensions to their relative sizes and functions, while procedural maps involve visualising a sequence of actions in making the product and externalizing them using illustrations and descriptions.

Students while conceptualising the artefact used varied means to think and negotiate their ideas: verbal exchange, gestures, sketches, structural analogies (use of existing concrete objects to denote a referent in their conceptualised design. For instance, use of rulers to represent vane assembly in the unit on windmill model seen within group interactions) and model-making.

Modelling

At times, students spontaneously made models to externalise their ideas and get a better feel for their visualisation. Many a times while discussing their design ideas of going about making things students used the concrete objects around. For example, in the bag-making unit, one of the students in a group would use the rough sheet of paper and demonstrate the folds to others in their group. Some of the children made paper or cloth models of a bag. Figure 5.10 gives one example of 2 paper models by one group of urban Marathi students.

In case of the unit on windmill, the end product itself was a working model so the discussion focused on visualisation of parts and its assembly. Students did use a lot of analogies and concrete objects while conceptualising components, evidences for which are discussed later in this section.

In the third unit on puppetry, students made paper templates prior to the making phase. This helped students visualise for themselves how the components would fit together in making a puppet. Example of a puppet template and the corresponding finished product is given in Figure 5.11.

Quantitative reasoning: Estimations and proportions

Quantitative reasoning was indicated in the depiction of dimensions and units, labelled lengths of parts and whole, measurements of raw materials and estimated quantities annotated or listed. Some of the evidences for quantitative reasoning also came from gestures and discussions about design decisions.

Fig. 5.10: Examples of paper models made by a mixed sex group in the Urban Marathi setting that helped visualise their group's bag. the bag has their group's name "Veer Savarkar" on it.

The unit on bag making was, for many students, their first exposure to making quantitative estimates in authentic contexts. Even so, the urban groups managed to show dimensions and units in their technical drawings and procedural maps of their bag design, though conventions were not followed. Students' ability and readiness to make quantitative estimates and depict measurements and units through labels and annotations improved as they progressed from the first to the third unit. There were instances of very detailed dimensions in the technical drawings of puppets among most groups, including the tribal groups. The example of a technical drawing for their puppet character by a Rural Marathi group in Figure 5.12 is a case in point. Besides, an increase in the number of resources to be manipulated in a designing task, as in the windmill and puppetry units, offered opportunities for measurements and estimates.

Estimates of sizes and relative proportions, component parts and their assembly, all constitute important aspects of design reasoning. This is especially the case when designers depict dimensions and use conventions in their drawings. While it was

Fig. 5.11: Example of a paper template and the finished product of a supernatural character of a demon made by a mixed sex group in the Rural Marathi setting

easier for students to label and annotate the measurements of a single part, or several independent components, it becomes difficult to be consistent in measurements and labels when representing composite parts or an assembly of parts. This was seen for instance, when an Urban Marathi group labelled the three segments of a strip as 5cm each in a (two-strip) cross, while the total strip length was shown as 10cm (see Figure 5.13).

Students' reasoning is revealed through the estimates of the cost incurred in making their product. An exercise in costing engaged groups in discussing about resources and estimating the cost and market value of the product that they set out to make. Students' estimates did not take into account the materials that could be reused or efforts and labour in making a product. On cueing, students did make efforts to incorporate the idea of reusables. Perhaps, a session devoted to costing, including exercises for students are needed. One such interesting conversation between a researcher and a girls' group in the Urban English setting, demonstrates students problems in mak-

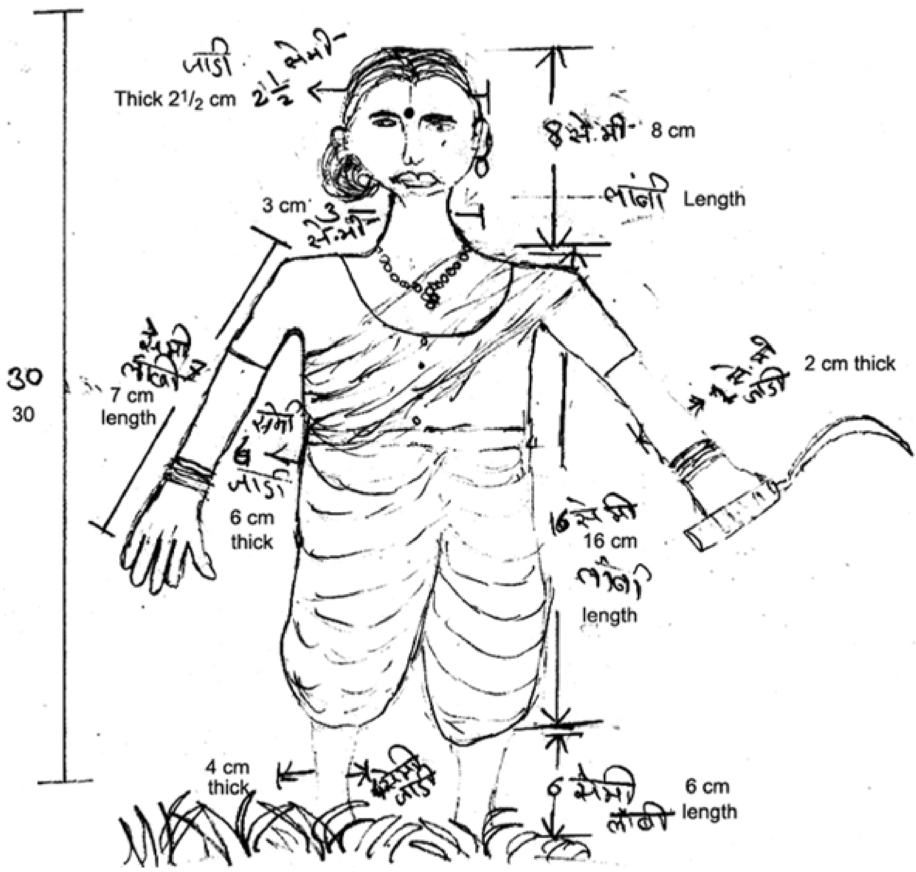


Fig. 5.12: Technical drawing of a female puppet character showing detailed estimates of size.

ing cost estimates of a specific kind of resource, namely the reusables and how it was resolved through a conversation.

(R = Researcher; G1: Girl student; G2 = Another girl student)

R: How many days do you think a ruler lasts?

G1: I don't know.

R: When did you buy your ruler?

G1: In January

R: How many months have passed since then?

All girls: (spontaneously) Five months.

R: So let's assume that a ruler of your kind can last for six months.

G2: But a ruler can break?

R: But if I use it carefully, will it last for at least 6 months.

All the three girls agreed.

R: So what is the cost of your ruler?

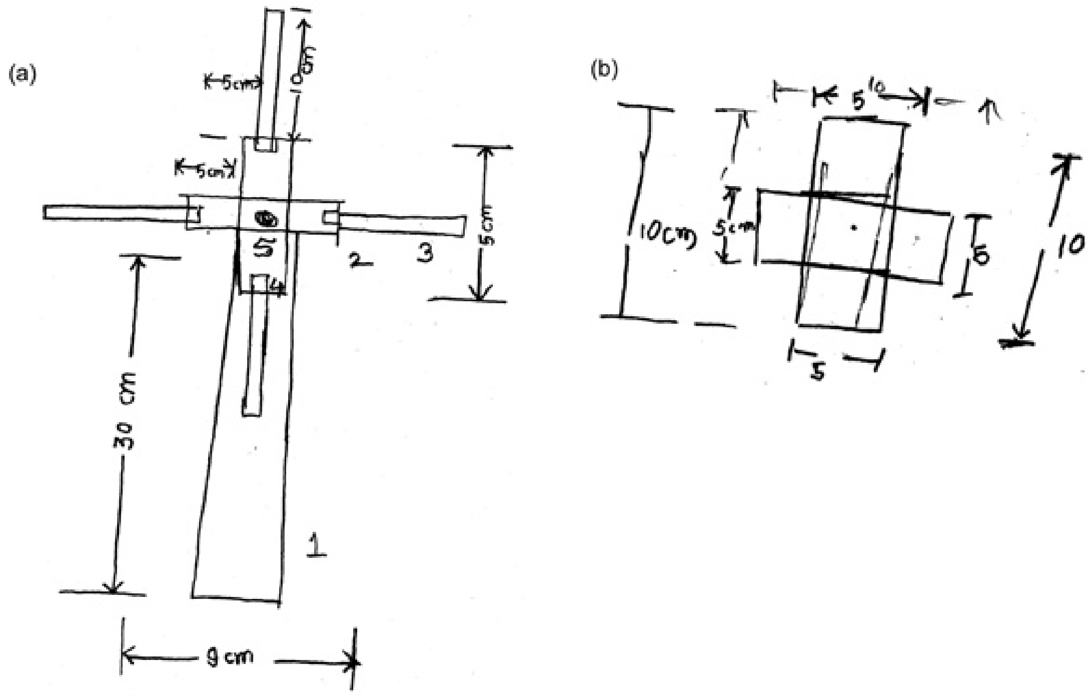


Fig. 5.13: Problem of quantitative estimation of length can be noted in the partially assembled part of a vane assembly by an Urban Marathi mixed-sex group. Note that dimensions of the length of strips do not total to 10cm depicted in their technical drawings.

G1: 2 Rupees

R: You have been coming here since...

All girls: Monday

R: and you have been coming for 3 days. In 2 days more you would have made a bag. So roughly if 1 week goes for making a bag, then in a month, how many bags can you make?

G1: About 3 bags (R did not correct this answer)

R: In six months?

G1: About 18 bags.

R: So if one ruler can last for making 18 bags, how much would making a single bag cost in terms of the cost of ruler.

Similarly R asked them to calculate for other items like pencil, eraser, needle, etc. They seemed to have got an idea of approximating the value of the objects used in making their product.

Problems in visualising and depicting the structure of a simple object as a bag carried over to the technical drawing and the list of materials. For example, while estimating the quantity of material for the bag, one of the groups mentioned the length of their bag as 35cm, but while writing they did not take into account the other side of the bag, which would read 35cm. They had problems in making rough estimates, identifying and depicting the units. This problem was noted among students in all the three settings. Some measurement activities were included in the subsequent trials.

Knowledge and skills of estimation affected students design and the finished product. For example in the unit on bag, a mixed sex group had not taken into account the margins that would be used in folding and sewing the sides of their bags. Hence they had to compromise on the size and the resulting bag was smaller than what they had planned. Besides, they added a pocket to it which meant use of more materials than what had been planned.

Students' difficulty in estimating and measuring has been summarised in the researchers' logs. It represents diagnosis of the problem with reasoning and solution(s) for the problem. This excerpt from the log also captures the nature of feedback in the logs by researchers.

> While interacting with the groups, I realised that they find it difficult to image an approximate size. The following observations indicate that the students need to build on 3 aspects of measurement:
>
> 1. The idea of units is not clear to most students: When asked about the size almost everyone give numbers but needed to be repeatedly asked about the units. For e.g. they would say that they require a paper of size 20 for their bag.
>
> 2. Confusing technical words: Words *laambi* (length), *rundi* (breadth) and *uunchi/jaadi* (height/thickness) are used to show the details of any object. One urban Marathi group was a bit confused about the words. I had to demonstrate using a box the things they need to measure when they wanted each of measures. (These technical words can be confusing and a better exposure of these with concrete objects as boxes, books, etc. would help them understand better.)
>
> 3. Children lack an idea of estimates/approximations: Almost all students had some tentative idea of the size but they find it somewhat difficult to make an estimate of the size of a visualized object like bag. One of the mixed sex groups found it difficult to mention the size of paper, and wrote an arbitrary number like 20cm. I had to help them by asking questions like – what will you need to measure the cloth/paper, how

much can this *patti* (ruler) measure? Measure this plain paper and tell me the size of it. So if this paper is approximately 30cm in length, how many paper/s of this length will you need? (Exposure to a range of objects of different sizes, and encouraging them to make a rough estimate might help them in sharpening their approximations.)

Assemblies, joints and reinforcements

Objects may involve simple and complex assemblies using different kinds of joints. Besides, properties of the material used in the assembly play a decisive role in the range of joints that are possible. Hence, in order to understand the kind of joints and reinforcements used by students, it is necessary to know the kind of joints a material affords and its types. In the three D&T units, the principal raw materials used by students were paper (includes cardboard and cardpaper), cloth, wood (includes wooden sheets and blocks), tin-foil and plastic. Of all materials, wood involves diverse kinds of joints followed by paper and cloth. The range of possible wood joints are of nine kinds as shown in Figure 5.14. Different materials afford varying degrees of joint compatibility. Paper to paper joint is easier and stronger than paper and plastic. Though materials differ by way of their composition, the sheets of materials allows certain kinds of joints. A simple lap joint is possible in wood, paper as well as cloth. However, the cloth puppet affords the use of two basic kinds of joints, namely; lap joint and interlocking, achieved normally through sewing.

Lap joints were the preferred joints for assembly of parts among groups of students across all settings in the windmill models and bags designed using card paper (15 out of 18). Gluing emerged as the major way of joining bag parts. However, none of the groups in any setting had designed reinforcements of the edges. It was only when they were testing that they realised that they needed to strengthen the joints and corners of the bag.

Puppets of all groups were designed of cloth and involved little paper material. Sewing was the most common means of joining, followed by gluing of accessories. While students largely used simple lap joint to show assembly of the vane parts to form a vane structure (14 out of 19 groups) and butt joints for assembly of tower parts (11 out of 19 groups), groups across all settings used 6 kinds of joints in their windmill design (simple lap joint, double lap joint, strap joint, butt joint, scarf joint and double

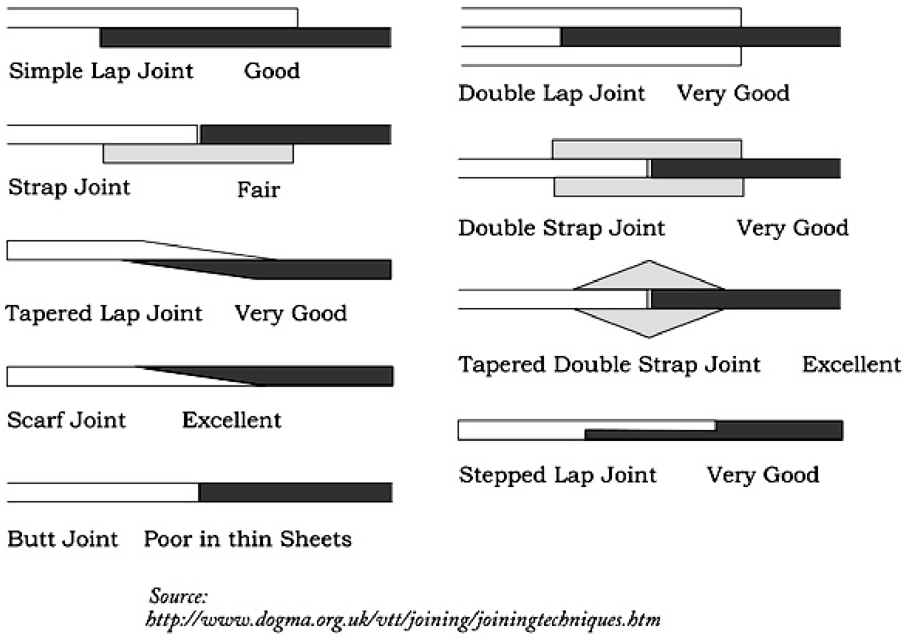


Fig. 5.14: Range of possible joints.

strap joint).

Strategies to reinforce joints reflect students' ideas of stability and durability. For example, 5 of the 6 tribal groups made crosses of thin plywood strips across adjacent tower poles. They possibly got the idea from large towers carrying electric cables often seen in the vicinity of their school. The tower structure used by rural groups can be noted in the picture of all windmills made by the rural Marathi groups in Figure 5.15. The sixth tribal group, which had a different design, reinforced a butt joint with a strap joint.

Fig. 5.15: Structural similarity of tower design in the windmill models by rural Marathi groups.

Use of symmetry, tessellations and repetitions

A design-and-make task is a highly motivating and relevant context for children to learn about shape, space and measurement.

Symmetry was observed in almost all components of the products in the design productions in the three units. Interestingly, though all bags made were symmetric, decorative patterns on them were largely asymmetric. In the windmill unit, most of the groups opted for a symmetric vane and tower structure. In puppetry, the main issue was that of maintaining a balance between two halves of the puppet about two planes. The puppets in all three settings were designed to be symmetric about the sagittal plane (the imaginary plane that bisects a human body into two lateral halves), as well as the coronal plane (the imaginary plane separating the front and back of a humanoid character).

Though all groups showed symmetry in their design and technical drawings, they did not use it to their advantage in the plan for making or cutting materials. They repeatedly depicted the operations on identical shapes as many times as they needed in their design: the vane was drawn four times to show that four vanes had to be made before assembly. Most groups did not recognise that a single vane with an annotation for making four pieces could have served the purpose. This may have been their understanding of a procedural map. Later, they had to cut out these identical parts from sheets of material, say wood, foil, etc. Only a few groups partially tessellated the shape of the part on the sheet to economise on material use (see Figure 5.16). Most groups planned to cut each shape in isolation: like all triangular shapes arranged with bases along the same edge of the sheet. Perhaps, the mental rotation and reorientation of imaginary objects needed for tessellation will come from instruction and exposure, while discussion of issue of economy of resource use may motivate them to use symmetry and tessellation.

Analogies in conceptualising and reasoning designs

Design involves analogical reasoning. Thinking with analogies implies mapping of knowledge from known domains to domain of the conceived object. Analogies may be visual or conceptual. Visual analogies involve similarity relations. Conceptual

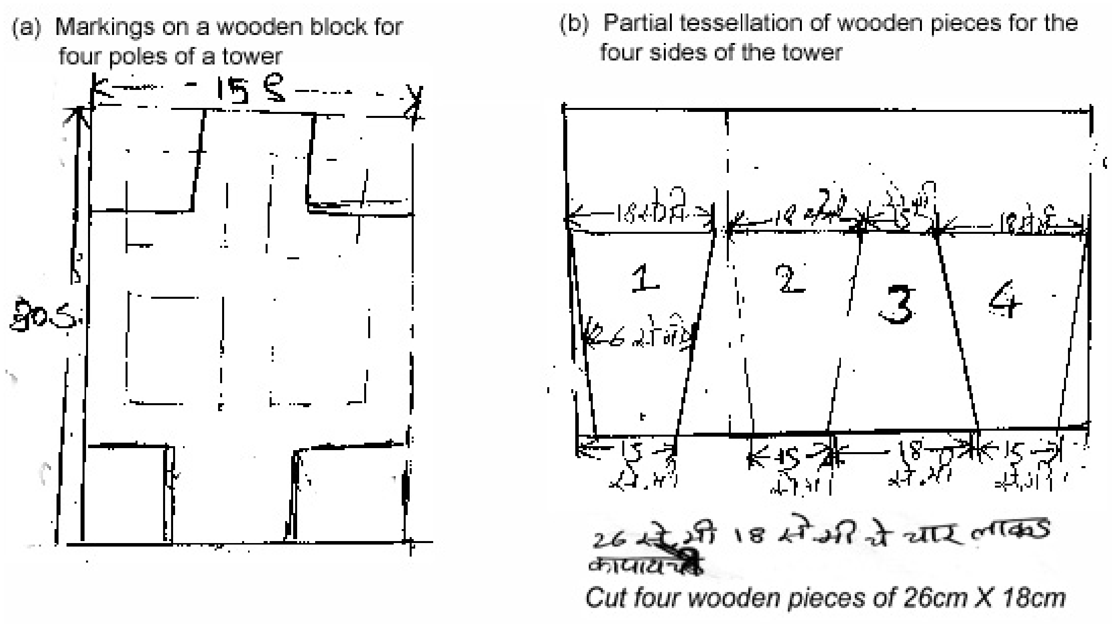


Fig. 5.16: Markings indicate the planned use of material resources: (a) With markings along the edges; (b) Idea of partial tessellations in economising the material (resource) used by a Rural Marathi group in their procedural map of windmill.

analogies are mappings of widely different source and target domains and may involve transformations to accommodate the borrowed information in the target domain. Reasoning by visual analogy is an important strategy in design problem-solving which involve ill-structured problems (Goldschmidt 2001).

Several groups of students used analogies during the exploratory stages of their design. Almost all the analogies were of the visual kind and were seen in the audio and video data. They were recorded as gestures seen in videos and vignettes, transcribed from audio. Analogies were more commonly observed during the design explorations of a complex product like windmill, and there were fewer examples of these during the design of a bag or a puppet. The extent of analogical reasoning in the discussions of design was similar across the three socio-cultural settings.

Explorations using sketches involve *interactive imagery* where designers do not merely identify analogies, but create them by imagining a target configuration. In the process of mapping and transfer, the source may be retrieved or transformed, or actually reconstructed and reorganized. Hence, neither source nor target are stable representations until the transfer has been completed (Goldschmidt 2001). One such case was the analogy for the vane structure. The exploratory sketches may have involved a conceptual analogy. The design exploration of vanes for an English medium group began with the sketching of a five-pointed "star" as noted in Figure 5.17. This evolved through several exploratory sketches into a vane structure of two crossed rectangular strips. In their procedural map descriptions, a tribal group used the analogy of the size of a thick nail to specify the size of a hole in a wooden block.

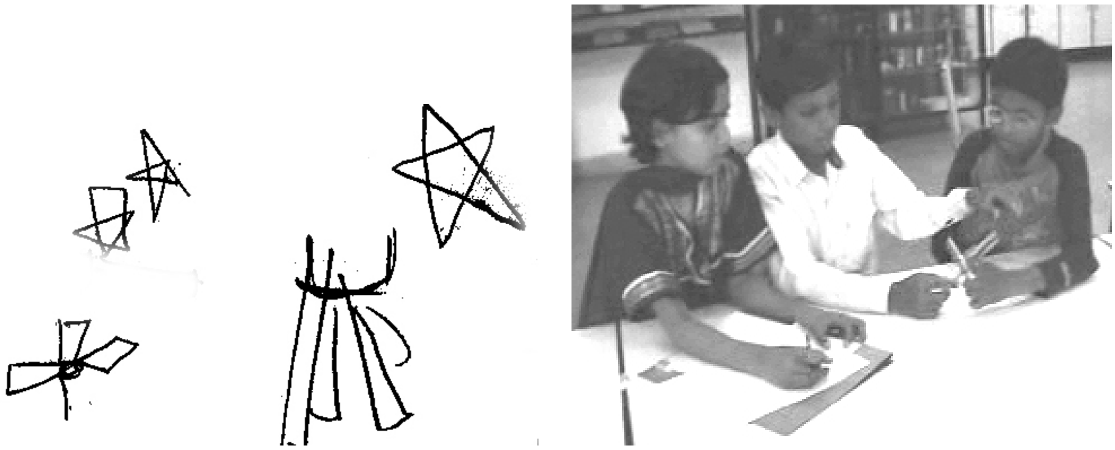


Fig. 5.17: Conceptual and visual analogy in design in the unit on windmill model

Students also used objects around them to explain the envisaged structures during negotiations within groups. While discussing the windmill design, an urban Marathi group (all boys) used a ruler as the tower, and another (mixed group) used two crossed rulers to help develop ideas about their vane structure. Other objects in their surroundings such as a tripod also inspired the tower design of a couple of groups (as seen in video recordings). Students spontaneously made visual analogies while they explored their design and reasoned about the components' structure and function. (See Figure 5.17)

5.5.4 Knowledge and skills in depictions, writings and organisation

Students' ideas of space were reflected through the kind of words and phrases they used to describe components and its assemblies in their procedural maps. Students' often used the non-relative orientations "vertical" and "horizontal" as noted in their writings in the bag-making unit, described shapes of components as "cylinder shaped" and referred to relative proportions like "equal parts" or "a hole the size of a nail" as observed in the list of materials and procedural maps for the unit on windmill model making. McCormick (2004) reports that while designing students tend to think in such qualitative terms rather than making quantitative and objective estimates. He refers to this as *qualitative thinking.*

Students' writings and poems served as means for them to express their ideas about the artefact to be made. This was especially the case for the rural students. In the first trial, these students were shy and did not speak beyond their name and group's name. While communicating their design and evaluation of their finished product (bag), they covered their faces with files. The same rural students however wrote pages about their windmill and puppet; some even wrote poems. Students' poems reflected their competence in synchronising rhyme and rhythm with their knowledge of materials, structural properties and functions of a windmill. A poem by a girl in Urban English setting is reproduced in Figure 4.6.

After they had been given a brief exposure to visuals and handled related objects in the three units, students' described the windmill in great detail, with external features such as the number of blades (2, 3 or 4, but they never exceeded the number 4), size (big, small) and shape (round arrangement of blades, not round). They included materials for the tower like cement, stones, bricks, wooden or iron; and functions such as lifting water, for generating electricity and to grind grains and make flour.

Evidences for acquisition of knowledge and skills can be noted in the changes observed as a result of either the engagement in a particular activity or exposure to a particular range of artefacts. These could be facilitated either through peer interaction or through an intervention by researcher. Students willingly shared the knowledge of artefacts that they gathered from their experiences and investigations outside classroom.

Learning to make procedural maps

The procedural maps consisted of an illustration and an accompanying written description for each of several steps in students' plan for making. We looked for the following characteristics in students' procedural maps:

- Does every step have a text and an illustration?

- Are illustrations labelled, and do they preferably indicate process or outcome of process or both?
- Does the text in each step correspond to the illustration?
- Are dimensions indicated in the illustration or description or in both?
- Do the steps follow each other in sequential order, wherever possible?

Students were given an exposure to an exemplar procedural map. The procedural maps for the windmill model among the groups in the two settings were an improvement on their bag unit maps.

The urban English groups, which engaged in these units after the units were completed with the other two groups, were exposed to the procedure for making a pinwheel in their first unit, namely the bag unit. Once the students had learnt the skill, their procedural maps improved qualitatively in their later units. The descriptions became more elaborate and referenced to the illustration. Among the three units, the rural groups had textually elaborate descriptions in their procedural maps.

Despite exposure to one or more exemplar procedural maps, students represented the anticipated actions for their making in several different ways. They had illustrations and descriptions on separate pages, steps in the description corresponding to the steps in the illustration. In some cases a description was followed by an illustration, which was followed by the description of the next step, and so on.

Analysis of students' writings in procedural maps

Analysis of the procedural map could be in terms of semantic clauses or in terms of verbs which are indicative of actions. Understanding through clauses gives a macro view.

Analysing clauses: macro analysis

It was possible to analyse the written description in terms of the simple clauses by excluding conjunctions, as there were no complex sentences. They were largely compound sentences with multiple simple clauses or sentences. The number of simple sentences, which could be categorised either as declarative or procedural, corresponded to the number of verbs used. The framework for the analysis is indicated in Figure 5.18.

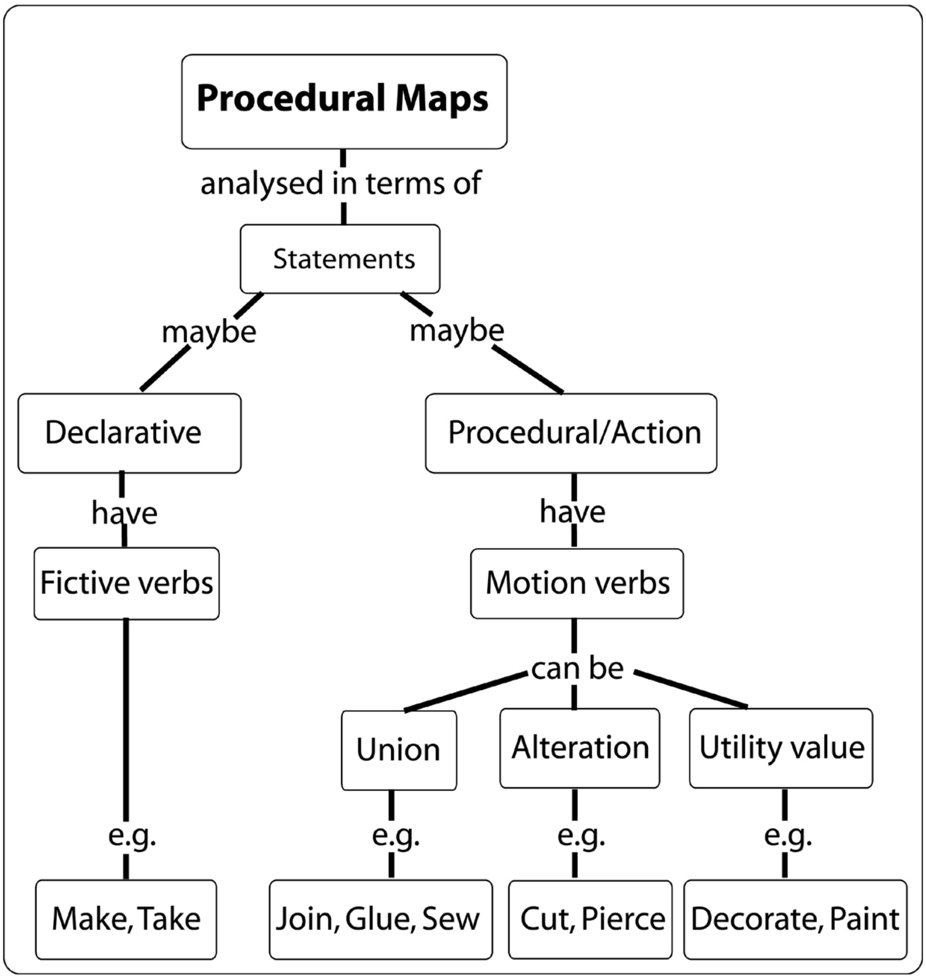


Fig. 5.18: Framework for analysis of the writing component in students' procedural maps.

Declarative sentences described an object, in terms of its existence, location or property. On the other hand, the procedural clauses are about taking actions. Table 5.12 gives a few illustrative examples, one from each setting, of the declarative and procedural clauses. Since the procedural map is a summary of actions in each step of anticipated making, the procedural clauses (statements) far outnumber declarative ones. Most of the urban students ended their procedural map description with a declarative statement (e.g. "Now your windmill is ready!!!!"), possibly an influence of exposure to recipe-based descriptions, such as in cooking recipes, shown in several media like the TV and Radio.

Table 5.12: One example from each setting illustrating the declarative and procedural clauses used by students in their procedural maps

Settings	Declarative clauses	Procedural clauses
Urban Marathi	This beautiful bag is ready	Glue the beads on cloth with Fevicol
Rural Marathi	Vanes 10cm in length and 3cm wide	Cut it into two equal halves
Urban English	Aha! Your puppet is ready!	Make a hole at the intersecting point of the blades

Analysing verbs: micro analysis

Hegarty (2004) in her work on mechanical reasoning, where she asked students to visualise movement of pulleys shown in a diagram, categorised the verbs used in their descriptions as (i) fictive verbs (to be, to have) and (ii) motion verbs (to push, to lift, to travel). In the present study, students' procedural maps occurred in three different D&T units, with differing levels of mechanical reasoning involved (most for the windmill unit). In order to analyse the verbs that describe diverse kinds of actions possible in the three D&T units, the "motion verbs" category used by Hegarty has been subdivided in our study into three sub-categories. Students' procedural maps, being plans of action, had very few fictive verbs. The action verbs in students' descriptive writings were classified in terms of the context of making as follows:

- actions of union e.g. *attach, stick, join, sew*
- actions leading to physical alterations of materials e.g. *cut, hammer, drill, make a hole/ slit, stuff*
- actions that fall in neither of the above categories

The total number of verbs in the procedural maps of groups in the three settings in the three units are summarised in Table 5.13. The average number of verbs used per group increased from the bag unit to the puppetry unit for the urban Marathi and rural settings, the increase being steepest for the rural setting (refer Table 5.13). There was negligible difference in the average number of verbs used per group between the bag and puppetry units in the case of the urban English setting, with a marginal increase in the windmill unit.

Table 5.13: Number and average number of verbs in the three D&T units in the three socio-cultural settings

Setting	**Urban Marathi**	**Urban English**	**Rural Marathi**	**Total**
Bag	59	46	07	112
No. of groups/Average	6/9.83	6/7.67	6/1.17	18/6.22
Windmill	97	105	51	253
No. of groups/Average	7/13.86	6/17.5	6/8.5	19/13.32
Puppetry	90	86	170	346
No. of groups/Average	6/15.0	6/14.33	6/28.33	18/19.22
Total	246	237	228	711
Total no. of groups/Average	19/12.95	18/13.17	18/12.67	55/12.93

Analysis of the verbs gave insights on the use of various verbs by students in the three settings across the three units. The two notable points are: (i) That there was a quantitative progression in descriptions in the procedural maps across the 3 units from bag to puppetry for the rural Marathi and urban Marathi settings, the difference being more dramatic in the rural case. (ii) That there was little difference in the average verbs per group across the 3 units for the urban English setting. The urban English students who were confident and had good communication skills did not show much change in the number of verbs. The Marathi students showed a progressive increase and increment was most vivid for the rural Marathi sample. The rural sample who were in the first unit very shy and had poor communication skills showed a marked progress in their language abilities.

Materials and their diversity across the 3 units

Complex designs, having several functional (other than purely aesthetic) components, offer scope for use of diverse materials. Each group was asked to include a list of materials indicating the quantity of material required for each of the components of the envisaged product along with the technical drawings. This was an effort to encourage students to anticipate the kind of materials and tools that would be required to actually make an object. We classified the objects listed into four categories: main materials, joining materials, tools and decorative materials.

Main materials are those that constitute the bulk of material needed for making essential components other than the accessories (decorative materials). For example, paper for making the body (container) of a paper bag would be the main material and cloth required for making the head, torso of a puppet are the main materials. Joining materials are those that bring about union, e.g., glue, nails, wire, etc. Tools are those instruments that bring about a change or transformation in materials, like the scissors, needle, pencil, etc. Decorative materials add aesthetic value to their products.

The unit on windmill model offered scope for using different materials not only because it was an assembly of several components, but also because each of its components could be made using one or more of a variety of materials. The tower, the vanes and the axle could all be made of different materials in a windmill model. Besides, the tower itself could be made from either wood or a sand-filled container, which in turn could be of tin or plastic. The variety in materials also needed a variety of tools to manipulate their shapes. On the other hand, objects in puppetry and bag units were made from similar materials, such as cloth or paper, using similar tools.

Decorative items were listed in larger numbers in the bag making and puppetry units, and were almost non-existent in the materials list in the windmill unit. The puppet characters, which reflect society, were shaped by the socio-cultural dispositions among all Indian students. Ornaments (necklace, beads, bangles, armbands), tools of a profession (scythe, spear), decorations and accessories (peacock feather, crown) are integral to representing humans. Bag making was the first unit in the trials, an item of personal use which is valued for its aesthetics, a factor which may have contributed to the bag unit being replete with decoration items.

5.5.5 Progression within and across the three D&T units

Progression suggests directionality, that is, moving from one state to another, in terms of knowledge, skills or understanding. Indications of a change does mirror the learnt skills, knowledge and procedures while engaging in the three D&T units. This section gives an overview of what changed within a unit and across the three units. We believe that these would have potential implications for developing D&T units appropriate for the rich and diverse Indian context.

Refinement of design ideas within a D&T unit

In each unit, students refined their design ideas from the early conceptualisation mediated by exploratory sketches, through technical drawings, procedural map, making and even in their evaluation of their finished products. Hence, some ideas of refinement get discussed even in a later section on making, which compares refinement of ideas from designing (design productions) to making (actualisation).

Progressive refinement of ideas was noted within all three units. The designs among all groups evolved in two major ways: in terms of shifts in shapes and assembly of components and shifts in material choices. Early in the exploration of design, a number of ideas were negotiated both through verbal and non-verbal communications as well as sketches. Some ideas disappeared from the sketches, while others were refined through the design process, indicating students' evolving ideas and cognitive shifts. An English group started with a composite vane structure in the shape of a five-pointed star; then decided to broaden its vertices and the structure evolved into four truncated pyramidal vanes held together with glue. Similar shape transformations included extensions of vane length, moving from smoothly curved ends to acute vertices.

Students considered possibilities of materials for each component and changed their choices during the process of designing. In an English group, the vane changed from a flat, truncated pyramidal shape to be made from a sheet (of cardboard or foil) to plastic spoons, and from a tower made of wooden blocks to a bottle filled with pebbles. In an urban Marathi group, a tin container filled with sand replaced the cube-like wooden box for a tower.

Progression of design cognitive activities across the three D&T units

The design productions improved in terms of clarity and representation in the later units. The earliest unit on designing and making a bag had procedural maps, which had statements of unconnected actions in anticipated making of the bag. However, as the groups moved on to the other unit on windmill they elaborated details of each of the components but little of assembly. In the third unit on puppetry, their procedural maps had greater textual description. The procedural maps were analysed for the content and the semantic relations between descriptions and accompanying illustrations. A considerable difference was observed in the procedural maps which had more dimensions and labels, had clarity in detailing the procedure at each step and had neatly organised steps.

Change was also evident in students behaviour as they moved from one unit to the other. Those students who were known to be shy and less active, were seen to be actively engaging in activities. For instance, most girls in the rural settings who were shy and often covered their faces with files in the bag-making unit, could face questions and clarify doubts raised in the unit on windmill model. They successfully managed to stage a performance in the puppetry unit.

5.5.6 Socio-cultural influences on design

The productions of students in the three D&T units were influenced by the settings of the students, their school and socio-cultural backgrounds and their prior exposure to technology, relevant skills and knowledge. Differences were observed in the extent of explorations, the use of X-ray diagrams, the descriptions in the procedural maps, the diversity of materials used, prominent features discussed by them in the design context (longevity and strength discussions in the videos) and the collaborative practices seen in groups of students in different settings.

Extent of explorations in the different settings

The urban groups were more prolific in making exploratory sketches than the rural groups, who had a tendency to erase and redraw on the same paper, even though they were instructed to retain all their rough work. Their tendency to be conservative in the use of resources limited our access to records of their design ideas. Our observations on the extent of explorations in different socio-cultural settings, point to the influence of the contexts in which the D&T units were carried out. On an average, urban Marathi groups made more explorations (24) as compared to the English groups (15). Similarly in the unit on bag, the body of bag had much more explorations than for the handle and its assembly. The number of explorations made by the urban Marathi setting (33) was more than those by students in the urban English (28) and the tribal (06) settings. Do students in different socio-cultural settings have preferences for strategies while designing their product?

Depiction strategies in the three settings

Students had more X-ray drawings in the unit on windmill than the other two units. Within the windmill model making unit, the rural groups had more X-ray depictions in their design productions compared to the urban groups. Nearly all rural groups (5 out of 6) had X-ray diagrams. Among the urban groups, X-ray drawings were observed more in the urban Marathi groups (4 out of 7) than the English medium groups (1 out of 6). The number of instances of x-ray drawings was also much higher (15) in rural settings, followed by urban Marathi (7) and just one instance was observed in the urban English groups. The differential levels of exposure of students might be a factor determining the strategies of design representations. More rural than urban groups' productions had x-ray drawings. However, some rural groups did use selective occlusion and dashed lines for occluded parts in their depictions. The presence of x-ray drawings, and more in our rural sample, may indicate a lack of exposure in some settings to graphics and graphicacy skills in the formal design context.

Knowledge and organisation

The procedural maps for the windmill designs varied in content and level of details for the urban and rural school students. In general, the urban groups had neater illustrations and brief descriptions of each step in making. Rural groups had detailed descriptions for each step and included dimensional aspects in the description rather than in the illustrations. The rural and urban Marathi students were very methodical in terms of the general layout. They demarcated the margins, drew boxes, made illustrations and wrote descriptions within it.

Issue of stability, strength and longevity in designs

While designing, students tend to have implicit considerations that are shared in the group of designers. These criteria though not explicated are negotiated among the group of designers as they are in the process of exploration and construction of artefacts. For example, in the case of windmill, students in different settings used diverse ways to address the issue of stability of the product and this was reflected in the kind of tower designs that groups made. The designs differed in the three socio-cultural settings. Urban Marathi had 3 groups who preferred to have a grouted pole design for their towers. The diversity in the design of towers for the urban groups was much high as compared to the rural groups who mostly opted for “stool-like designs” for the towers. The nature of materials used by students from different settings for the 3 units and the structures they produce also indicate the considerations of strength and stability by students in different settings.

Although there is plenty of scope for variability in terms of the use of potential resources, materials and ideas that could be brought to use, at some point in design students seem to hold on to a particular line of thought. For example, students tend to move on to an even number of vanes for their windmill model in most of the groups. Interestingly, among all the urban groups, at the end of making, most windmill models (attempted to have) an even number of vanes (4, 6 or 8). On the other hand, the tribal setting had half the groups who consistently maintained odd number of vanes in their design drawings. Thus, an even number of vanes was more prevalent in the urban groups than the rural. However, on an average the number of vanes for all groups is four, an even number. There seems to be an inclination among students from a socio-cultural setting, as if this is an implicit criterion or perhaps may be a matter of inconvenience while making. A further probe may give more insights on the causality.

Issues of aesthetics and use of symbols

The unit on puppetry, more than bag and windmill units, elicited students’ engagement with aesthetics. Students across all settings tend to concentrate on every visual detail, right from their earliest explorations. The focus was on details like the ornaments, dress-code, cultural attributes associated with a character like the stripes on body, shape of a bindi on the forehead, bracelets on arms, details of the attire for characters and even the colour of crown, sword and ornaments. All these observations point out to a deliberate effort and labour invested by the students in designing their puppet to make them lively and closer to the real world contexts.

The Urban Marathi students used religious symbols as *swastika*, *trishul* (trident), *taaveez* (lucky charm, talisman), and other cultural symbols as stripes on body, sacred thread on body, sindoor on the forehead, stone or bead necklaces besides popular symbols like *Mickey mouse*, roses, lotus, etc. in their design productions in the units on bag and puppetry. The urban English depicted popular TV cartoon characters like Pokemon while others used decorative designs made with sketch-pens and paints to decorate their bags. One of the English groups used stencils to make the decoration for their group's bag. The tribal students too depicted bindis on forehead, sindoor, bracelets and ankle bracelets, flower designs as cultural symbols. Such cultural symbols were used in their depictions in a greater number by the urban Marathi followed by the rural groups and the least by the urban English groups.

Students used a range of symbols and icons in their procedural maps as well. In their procedural maps, the English groups used referent labels, showed icons of tools (hammer, scissors) and making actions. Some of the rural and urban Marathi groups included "measuring and marking" as a significant step in planning and making in both drawings and descriptions. A rural group depicted a measuring device (ruler) with detailed markings alongside a wooden piece to show its length, but did not align the zero of the ruler with the end of the piece.

Collaborative interactions

Students were almost spontaneously immersed in discussions about the technological activities they engaged in within groups, with members of other groups and with researchers unlike what has been reported in a few studies in D&T education, where students found it difficult to talk about the technological activity (Fleer 2000).

As each group of students explored the designs, they negotiated ideas that emerged within the group through discussions as well as sketches, gestures and other non-verbal modes of expression. In some groups, individuals made exploratory sketches, and they had to negotiate with the other members to get these accepted even in a modified form. Other groups worked collectively, all members simultaneously sketching all over the page leaving very little graphical spaces. The evolution of sketches, especially in such "team sketches", showed evidence of *collective cognition* (Anning 1997). Students designed, redesigned or modified their original designs right up to the making and evaluation tasks.

Group members collaborated in visualising and organising the anticipated actions and produced the procedural map for their group. In most groups, one of the group members drew the illustrations for each step and another wrote the corresponding descriptions, often simultaneously. Other members of the group supervised and gave suggestions. Each group had to assign sub-tasks to each member. They sometimes assigned tasks based on skills typically associated with the individuals (carpentry work to some and cardboard or metal sheet cutting to others) and at other times they made a random assignment of the tasks.

Collaborative completion of design production was typically observed in the audio-visuals and in researchers' notes, in urban groups. A sentence started by one student was completed by another, a description by one student was depicted as an illustration by another and an illustration by one student was modified by another. These suggest a shared understanding of the design ideas among group members. Collaborations in rural groups, often involved collective discussions and then led to drawing/writing on paper with the others giving suggestions.

Most groups worked as *teams* towards construction of their planned artefacts, as all members collaborated in achieving a common goal. The members willingly took up responsibilities, helped each other in activities like cutting, boring, etc., besides the activities they had been assigned for themselves through work distribution. The video tapes and the products show the rich experiences of students' collaborations and interactions among peer as well as with materials and tools. As they went about the making, students handled and experienced a number of tools with the guided intervention of researchers.

In the unit on puppetry, collaboration within and between groups were structured. During the exploration of design, each student in a group had to make a drawing of how their group's puppet would look. The puppet was to be made by the group and hence it became essential for members in the group to ideate together and conceptualise their group's puppet. Group members discussed before making any drawings and though the exploratory productions made by individuals had surface variations in the outcomes, the sketches were nearly the same. The coherence of puppet characters in a story meant some degree of commonality in similar characters across groups. For example, two groups in the Urban Marathi setting both making soldier puppets negotiated to arrive at some common features such as the khakhi colour as the attire of their puppets, as also a cap on head and shoes. Similar intergroup negotiations were noted among the three groups in the Urban English setting, working on the three dwarf puppet characters. Figure 5.19 shows the sketches of the three dwarfs visualised by the three groups. Commonalities like the black dress, length of the puppet, the tapering cap and the decision to have dwarfs without feet/shoes were a result of intergroup interaction.

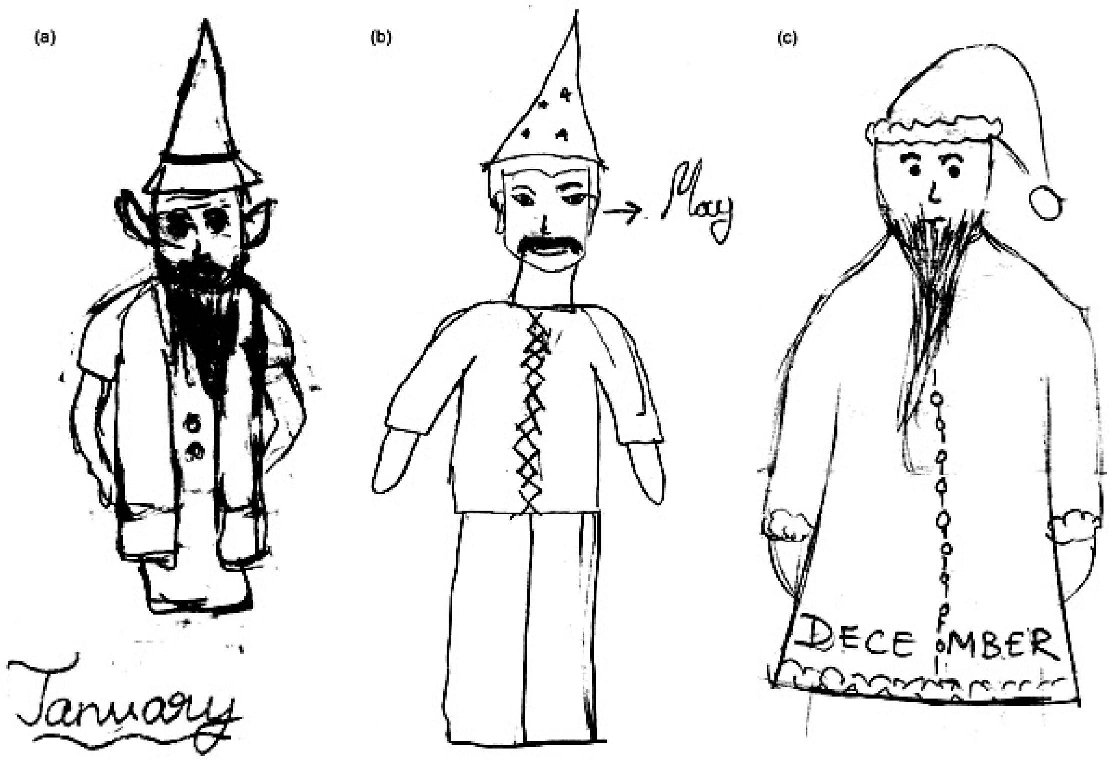


Fig. 5.19: Sketch of dwarfs selected by the three groups in the Urban English setting.

Work distribution involves assigning work roles to each member in a group by taking cognisance of the overall scheme of making. It requires students to chunk the activities into meaningful subsets. Analysis of the work distribution in the participating groups revealed three strategies used by students:

Person equals steps: Students chunked the making activity according to the number of members in the group. Thus, the steps corresponded to the number of individuals in a group. For example, if a group involved 3 members, the entire making was condensed to just 3 chunks.

Step-wise person: Students listed the steps and ascribed a step/steps to one member in each group. The list of activities thus guided the work distribution, which usually followed a sequence and the name of an individual could figure more than once in the work distribution.

- *Equal work distribution:* Governed by the number of individuals in the group and the idea of equal distribution in terms of number of activities, similar to person equals step approach.
- *Unequal work distribution:* Governed by either the dominance or skill assets of individuals within a group.
- *Dyad distribution:* A single chunk of activity was assigned to two members in each group. Essentially, it could be the same as *Person equals step* approach except that an activity was ascribed to two individuals. The number of steps could be more than the number of individuals in the group but each activity was shared.

Random order: No order or preference was suggested in the assignment of activities within a group. Perhaps it was a random assignment which came about as the group progressed in explicating the steps in the anticipated making.

5.6 Summary on analysis of design productions

The analysis of design productions thus provided evidences for students' cognitive activities. Students used a number of strategies to visualise, detail and communicate their ideas of the perceived artefact which they planned to make. It was interesting to note that students relied on exploratory sketches and gestures to formulate their ideas, much like adult professionals engaged in design. This draws our attention to the value of drawings in design visualisation and its role for classroom contexts as well. Table 5.14 presents a summary of the strategies used and instances in each of the units.

Table 5.14: Summary of the features occurring in students' design productions indicating the influence of the three D&T units.

	Criteria	Bag-making	Windmill model	Puppetry
1	Components	Body, Handle	Tower, Axle, Vanes	Head, Torso, Torso covering (Overcoat), Limbs, Accessories
2	Explorations per group	3	18	5
3	Enlarged views (actual numbers)	2	15	0
4	X-ray depictions (actual numbers)	11	23	4
5	Different materials used per group*	9	8	9
6	Materials listed (actual numbers)	167	159	160
7	Joint type	Simple-lap	6 types, mostly simple-lap	Simple-lap
8	Verbs in procedural map (Ave. per group)	6	13	19
9	Technical verbs per group	4	7	8
10	Text referred to illustration in procedural maps	08	10	11

Note: * Students list of materials included tools in the bag-making unit.

Beyond designing, into the making...

The journey from conceptualisation (design) to actualisation (making) is an important process integral to all D&T units. Conceptualisation (designing) and realisation of ideas into material form (making an artefact) are certainly the two pivots for anchoring enquiry into cognitive issues in D&T education. The product in the process of getting realised may go through a process of redesigning, which is in response to the needs arising in the ongoing process of making. Transformations in design ideas can give valuable clues about the features on which students made changes. Figure 5.20 attempts to capture the relation between designing and making in a visual. It therefore follows that design productions coupled with classroom observations of making activity hold potential of providing reliable insights into students' journey through the D&T units.

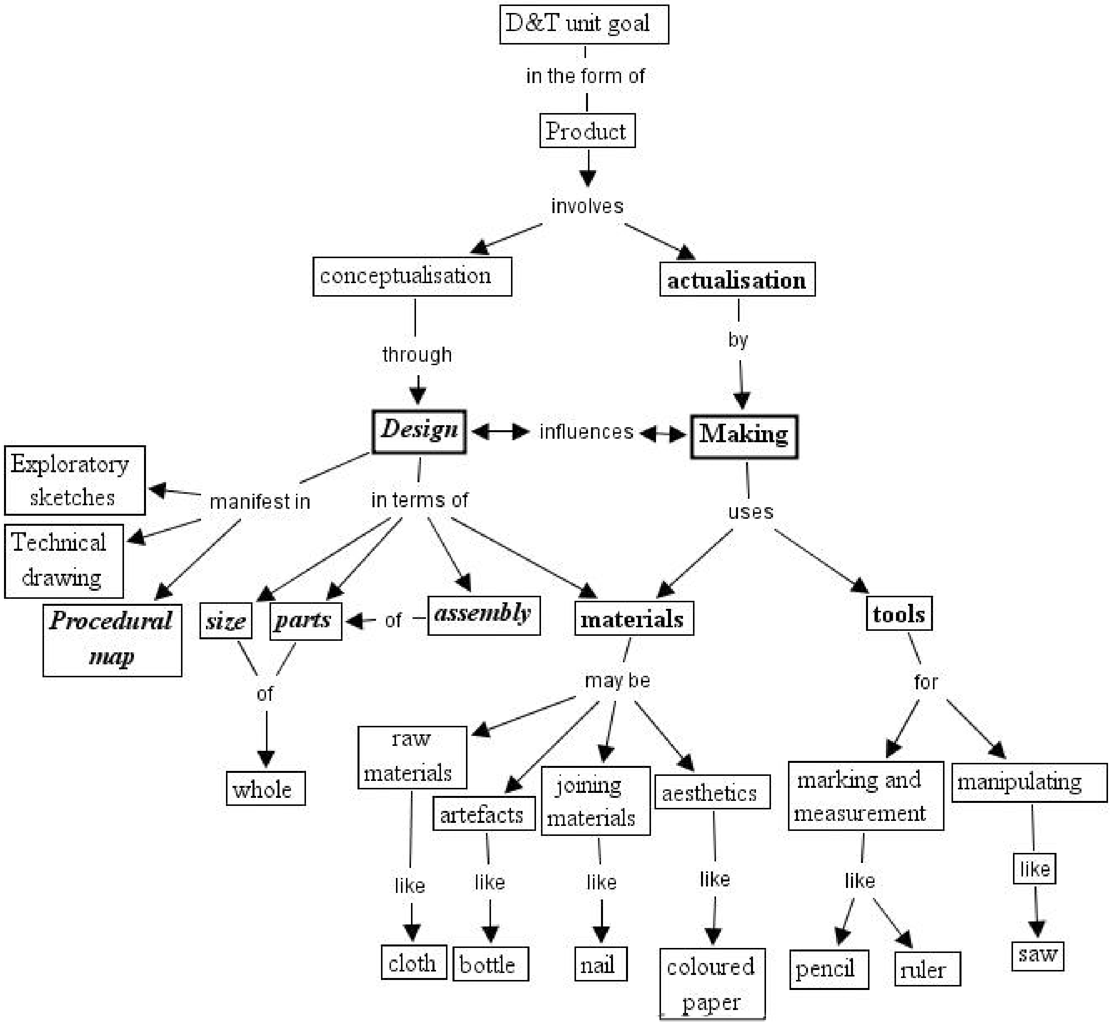


Fig. 5.20: Different aspects in designing and making a product to solve a problem.

5.7 Cognitive aspects during the making activity

Design conceptualised in and through design productions was translated into a product in the making phase. Since making is preceded by design, students' design productions are the thrust sources for referring to their conceptualised design. Post-making, evidences for change get revealed through instances or through indications of change cited by students in their evaluation sheets. Besides, comparison of design productions (conceptualised form) with product (actualized form) along with excerpts of student interactions help reconstruct a coherent review of instances that serve as evidences for cognitive engagements. Several cognitive aspects characterise the making of an artefact in a D&T unit, which are studied using the framework in Table 5.15.

Table 5.15: Cognitive aspects in the making activity

Aspects	**Features studied**
Visualisation of the artefact	• Redesigning joints and assemblies • Nature of changes: size and shape of the artefact, Number, shape and size of parts of the artefact, Materials asked for and used, Planned assembly of parts and that found in the finished product, and Joint types and the joining materials planned and used
Knowledge and application of material properties and processes	• Material preferences and tool preferences • Strategies for resolving difficulties in making
Exploration of tools and their use	• Evidences of reflective thought in use of resources • Students' choice of tools
Strategies for revealing and solving problems	• Evidences of students testing unfinished product • Other strategies for solving problems (Trouble-shooting)
Role of design productions in making	• Evidences for explicit reference to design productions • Evidences for shared design

The first four cognitive aspects are relevant in both individual and collaborative work environments. Collaborative environment affords a unique opportunity to study the last aspect of the role of design productions in making which is a continual evidence for formulation and development of design among naïve designers. The following sections elaborate the cognitive aspects in the making activity along with supportive vignettes and classroom observations.

5.7.1 Visualisation of the artefact: Redesigning

Students in all settings in all units were seen to change from their conceptualised artefacts as in design productions to what they actually made. The extent of changes varied in the three units. Many changes in the puppetry unit related to the decorative features, while in the other two units most related to issues of practicality such as strengthening the weak zones, measures to increase stability, modifying shape and form in order to achieve efficient functioning.

In the unit on bag-making, students' description included perceptual features of bag like size, shape and aesthetics. Materials, purpose and design issues required some cueing from researchers. Even after handling exemplar bags of a variety of kinds, perceptually salient parts like handle (big/small), orientation (vertical/horizontal) of bag were aspects most often discussed. This observation goes in line with the theory of emotional design proposed by Norman, who asserts that the sensory experiences are primary concerns followed by reflective actions (Norman 2004).

Changes in artefacts from the designing through making phases represent an ongoing cognitive process. In the first trial of the bag-making unit in Urban Marathi setting, nearly all the groups (except one boys group) changed from their original planning and drawing. Some of the changes were a matter of preferences and material availability, while other changes were taken as a response to thoughtful actions. For example, a boys group changed from a vertical bag to horizontal one. Another boys' group, changed their bag size because they could not get the folds right and in the process lost some of their chart-paper material. Later they could not get a coloured paper of an appropriate size and so suitably modified their design.

The modifications made by groups most often concerned assemblies and joints followed by aesthetic features, shape and number of parts. The predominance of redesigning in joints and assemblies while making, as illustrated in Figure 5.21, suggests that it was difficult for students to visualize and anticipate the assembly and joints prior to making. On the other hand, two of the 19 groups who had spent greater effort in the design stage on visualisation, as seen in their elaborate exploratory sketches, made far fewer changes in design while making (see Figure 5.22). Their products were nearly the same as in their procedural maps. Besides, assembly and joints formed an important part of their design explorations. This seems to indicate that design explorations are critical for the planning and making of a product and for honing students' visualisation skills. An elaborate exploratory phase would require the students to visualise and discuss the assemblies in their conceived product.

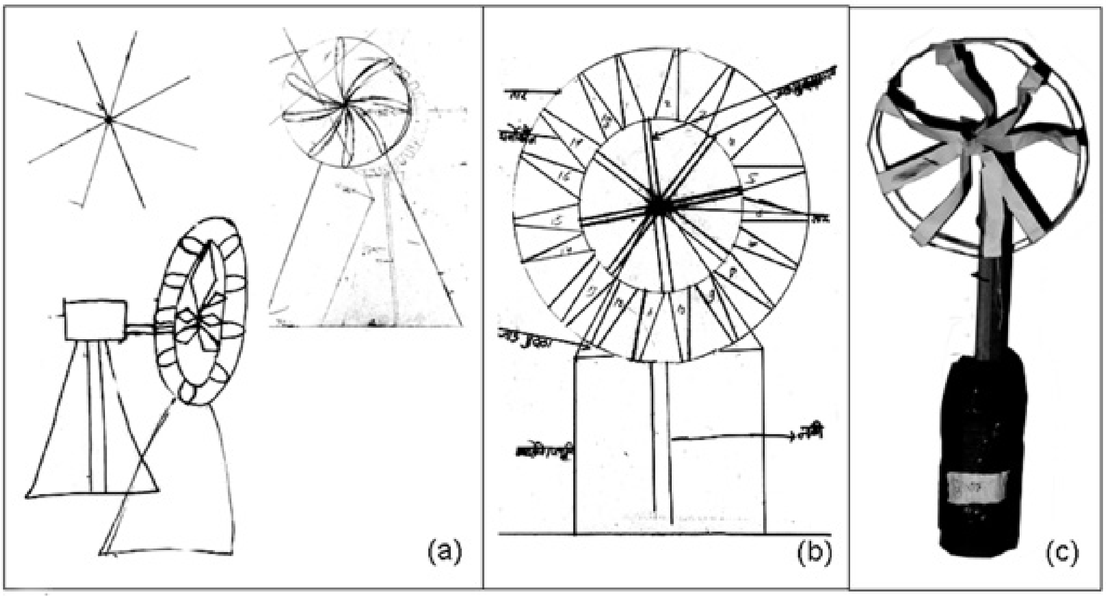


Fig. 5.21: Redesigning of joints and assemblies while making by an urban Marathi group: (a) explorations, (b) final step of procedural map, and (c) the windmill model. Though the shape of vane structure remained circular, the materials used, the design and its assembly evolved through the making.

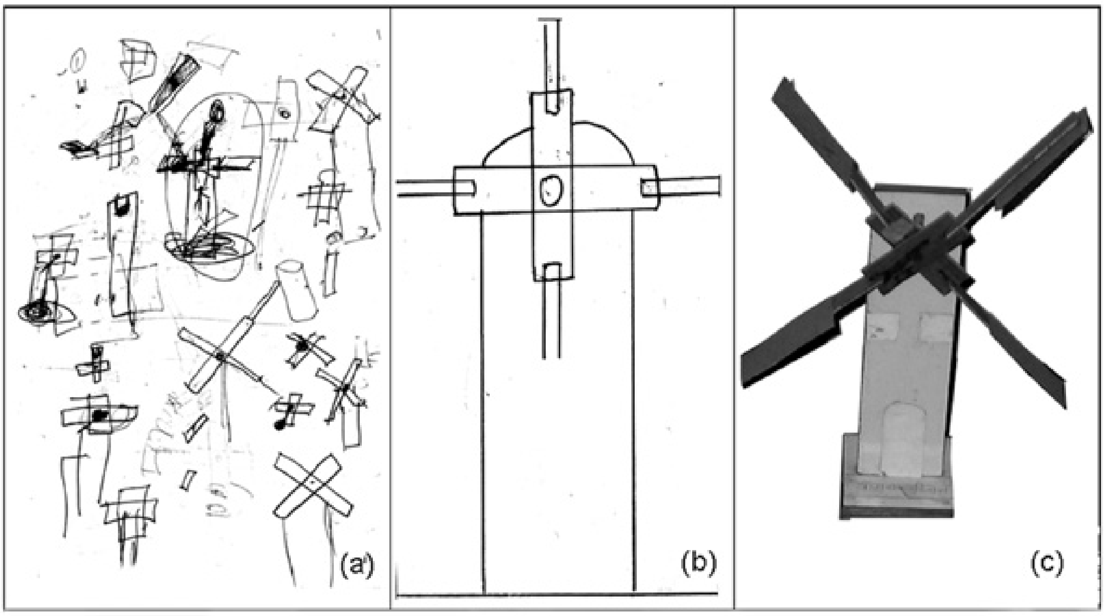


Fig. 5.22: Similarity between design and product in an urban Marathi group: (a) explorations, (b) final step of procedural map, and (b) the windmill model.

By the time the third unit on puppetry was tried, students had become conversant with the processes involved in the interaction. Often they moved onto the other session and even made comments on the section that would come ahead.

5.7.2 Knowledge and application of material properties and processes

In the unit on bag, subtle distinctions between cardpaper and cardboard came to be realised by students who were using these terms interchangeably. Students came across several difficulties in making the folds possible, especially those around the corners of bag. In doing so, many atimes, the region became very weak and was prone to tearing. Such a situation led them to think of reinforcements for base. Some groups tried to reinforce the mouth of their bags around the handles. Some groups discovered the qualities of materials and tried to use them as an advantage. For example, a mixed sex group in urban Marathi setting stuck cloth to the cardpaper from inside and stitched along the edges to ensure strength along the lines of weaknesses.

Assembly of vanes afforded an opportunity for cognitive transition in terms of students' knowledge of the properties of free standing components made from bulk material. Students encountered difficulties while assembling vane structures: tearing of vanes at their narrow ends, difficulty in maintaining a fixed relative position of vanes, and weak joints. In response to the problems, students modified their vane structures in shape and materials, and reflected on their strategies. For instance, one urban Marathi group used a thick and heavy cardboard for their vanes, discovered that the vane weight tended to tear its narrow ends and switched to a thinner card paper. In their evaluation, they wrote reflectively about this shift.

Students were given the materials that they had requested in their designs just before the beginning of the making activity. While designing they did not have access to a variety of materials and therefore had not handled the materials. During the making, a greater variety of materials than was requested for was made accessible to the students. Urban students made use of this access to try out materials they had not planned to use. However, despite a similar access during the making stage, the rural groups preferred a limited set of materials. Perhaps, application and use were constrained by the prior knowledge and exposure to material resources. While designing, students are like technologists, relying on their prior knowledge and experiences, graphicacy skills and visuo-spatial thinking. Engaged in the activity of making in a material-rich environment, they are seen to be like bricoleurs redesigning parts aimed at achieving workable outputs based on available artefacts, materials and tools. The braided handles in the unit on bag, adding a perpendicular surface to the vanes or tilting them along an edge in the unit on windmill unit, and inclusion of shoes for puppet characters in the role of soldiers are all cases that substantiate the bricoleur nature of students in making activities.

In the unit on puppetry as well, students exhibited their use of knowledge of materials and applied it in creative ways in staging the puppet-show. One of the evident things noted were the props in the stage-show which had to appropriately reflect the story context. Students in different settings devised ways and means of putting up the settings using the available resources. While urban students used locally available garden waste to create the ambience of forest on stage, curtains to decorate the palace and a thermacol waste to get the effect of a royal bed for the queen, the rural students used their local resources like cardboard and thermacol sheets to create the scary cave for the demon, grass props for farms and many small animal props to create the setting of a village. Students also checked and refined their dialogue delivery, background music and coupled their performance, including identifying points of stage entry and particular actions in the entire flow of events. After one to two retakes, they felt confident in taking up the final performance in front of an audience. Teachers, some of their friends and members of HBCSE were invited to view the final performance.

Students exhibited great competence in organising the flow of events in the performance. They gave significant value to the minute details of an introduction to the audience, lifting or rolling the curtain sideways right at the beginning of the show, match of dialogues with facial expression and movements of the puppets by the puppeteers. Student puppeteers made conscious efforts to display even the facial emotions (of anger, sympathy and obedience) along with the overt bodily expressions. Attempts were also made to bring out interactions between performing puppets like a handshake, exchange of materials (e.g. a rose), or a hard slap on face. Dramatic visual and sound effects were made to add a sense of reality and spice to the performance. e.g. the dramatic action of a puppet character, who is puking/ throwing up; the fearful atmosphere on entry of a demon (rakshas) or the walk through the forests with birds chirping coupled with a song in background. Stage support like physical settings, background music and songs, light arrangements that created moods of evening and broad-daylight, home and palace settings were all well co-ordinated.

5.7.3 Exploration of tools and their use

Bag making involved use of common tools such as needle, thread and scissors. However students tried using needle and thread with a combination which had paper sheets stuck to the cloth. Simple stitches were just sufficient for these students to make a bag sufficient enough to carry five books. Most of the bags were made of paper hence not many tools were used. Measuring tape or scale was a tool which students learnt to use through the course of making.

The unit on windmill model, required the most use of tools. Tools of diverse kinds, including those that were not asked by the students, were made accessible to students. Both boys and girls took the initiative to explore several unfamiliar tools and their function and operation while making their product. Sometimes, they approached the researchers, who helped in deciding the appropriate tool and guided them in their safe use. Once a tool was used by a group of students, other groups noted it and sought to incorporate it in their making as well. Selection of materials from among accessible resources and choice of an appropriate tool to work with are evidences of students' reflective thought in making.

Puppetry unit required students to get used to raw materials which was mostly cloth. Needle and thread were the main tools. Stable handling of scissors to make straight and curved cuts on paper and cloth got exercised. Most of the rural and urban English students did not know sewing and therefore sewing techniques were taught to them along the making. The rural students were taught sewing in the "Makeup session" through an exercise of making a handkerchief for themselves.

5.7.4 Strategies for identifying and solving problems

In the unit on bag, tearing of material around the weak zones such as around the handle, along the edges and the corners at the base region were the most frequently encountered problems across all settings. Students resolved it by reinforcing with additional materials. A mixed sex urban group, who had use a mattie cloth for their bag, had problems joining the handle. Finally they attached the handle by making holes in the cloth and inserting the handle through it. They tied knots at the base to keep the handles in place. A girls group from the same setting wanted to use the white strings for a handle but felt were quite slim for a handle. They braided three strings together to make a wide and decorative handle for their bag.

In the unit on windmill model, students used a variety of strategies to test the working of their unfinished product at various stages in the making. The test provided a validation of their making and a motivation to continue. If the test revealed problems, they either used a quick-fix solution or resorted to redesigning. An example of strategies used in redesigning was seen in the vane structure made by rural groups. Though all rural groups made their vane structures from tin foil, each group had a unique strategy of assembling the vanes: tying the vanes together using wires, nailing them in place, gluing them or using washers to fix them on the axle. During the making, groups took decisions about the workability of their vane structure, the mobility of the vanes and the strength of the tower.

Failing to find their desired amount of yellow cloth for making their puppet, the group making the dwarf named *May* sewed on a black coloured dress, similar to how the dwarfs were dressed, but stuck a significant yellow coloured mango shape on the cap. Even during performance of the puppet-show, students were able to overcome immediate problems. They displayed great competence in overcoming points of fumble in their final show. For example, they managed to make entries look dramatic inspite of some mismatch in the order. In the urban English setting, a rose had to be exchanged among puppets. However, the rose fell down and students quickly picked it up and merged it as if it was one of the acts in their puppet-show.

5.7.5 Role of design productions in the making

Did the design productions only serve as a cognitive step or were they used as reference material in the making process as well? This can be discussed with respect to students' reference to their design productions while making. The situation changed from the bag-making unit to the unit on puppetry. In the bag unit, which was a first exposure of students to design and make in the collaborative learning environment, students rarely consulted their drawings (design productions) and often ended up changing materials, designs and required a lot trouble-shooting, especially at the point of assembling.

In the later units there were stray instances of reference to production in the making activity but most students did not refer to their design productions. Yet there were significant similarities between their design productions and their finished product. In fact, students while working knew what they had to do next or what they had to contribute and were actively collaborating. Such interactions as seen through audio-visuals and the similarity between their conceived design and made product suggests that, once explored and conceptualized, the design remains in the shared memory of fellow designers and makers. Some groups, however, referred to their design productions while making.

5.8 Summary: Design and cognition

The chapter aimed to discuss students' cognitive engagement in the three units in the three settings. Students' learning trajectory was studied through classroom observations, students' design productions, and an analysis of cognition in making. Frameworks for analysis were generated to understand the design cognition involving naïve designers, with a first taste of design and make, in a collaborative learning environment.

Analysis of classroom observations showed evidences for the influence of students' perceptions of materials. Besides, costing, and judgements made by students played a significant role in design. These considerations were reflected in the process of designing and the conceptualised design. Classroom observations analysed for aspects of content and pedagogy showed that students benefited in their design when they were given practice activities on estimation and measurements, as well as an exposure to graphicacy skills and conventions of technical drawings. Through their engagement in design activities, students applied their knowledge (of materials and its properties), skills (of estimating, qualitative thinking, communicating, manipulating and critically evaluating) and values (aesthetic, economic, ecological) toward realising the product.

Students discussed structure-functional aspects of the artefacts they handled during the investigation phase. This motivated students to look for details of the artefacts. The structuring of collaboration and communication in the classroom interaction helped students express their ideas in different modes, such as, presenting and defending their designs and plans orally, writing poems and descriptions, drawing and using gestures. D&T units were found to enrich vocabulary, mediate integration of knowledge from diverse domains and helped students gain and use context-specific knowledge and skills across existing school subjects. The classroom dynamics of sharing ideas and resources, appropriating tool use and the resultant ways for resolving problems all formed an interesting atmosphere of lively researcher-student interactions.

Students' design productions showed several aspects of their visuospatial thinking, the most important being that they were able to visualise and conceive the structure of an artefact for a specified function. Groups visualized the desired artefacts using the verbal as well as non-verbal modes (gestures, exploratory sketches, signs). The more complex and unfamiliar the conceived artefact the greater the extent of explorations. Students' need to depict varying levels of details guided their choice of views and the selection of strategies, like X-ray drawings and enlarged views. Their sketches showed use of analogies while designing. The number of materials and tools used in windmill unit was more than in the other units. However, decorative materials were much more in the units on bag and puppetry. Initial ideas that shape the design (primary generators), issues of stability, strength and longevity and material preferences vary with the socio-cultural settings and the nature of the unit.

Qualitative differences between productions of students from different settings were analysed with no intent of making judgments. It revealed that the urban Marathi group had more explorations than did the Urban English or Rural Marathi groups. Rural Marathi students more than urban students had more elaborate writings in their procedural maps. The socio-cultural influences were reflected in the choice of decoration materials by students in different settings. Urban students used religious accessories and western cartoon characters, whereas the rural students preferred beads, bangles, etc. and drawings of flowers for increasing the aesthetic appeal of their artefacts.

Students collaborated in making the procedural map and completed them by each member working sequentially or all members working simultaneously on the same map. Besides, it was often observed that while making the artefact, group members working on different activities related to the artefact did not refer to their common design productions. They however communicated with each other. Yet, their finished products closely resembled their group's design productions. These suggested a shared understanding of the design ideas among group members. Students talked about the strength and weaknesses of their own and other group's design, the problems they had encountered while making and how they had solved them. In addition, they also reflected on aspects that can enhance the appeal of the finished artefact and help it function better. Appreciation of aspects of others' products and presenting criticism respectfully became a part of learning as students engaged in this exercise. Besides critical thinking, this exercise utilised both language and social skills.

Students engaged in exploration and modification of materials, discussing properties and functions right from the early conceptualisation phase through making to reflecting. They refined their design ideas in the making as well as evaluation phases suggesting that designing pervaded all phases of the *communication and collaboration centred model* for teaching-learning of design and technology.

Chapter 6

Summary and Conclusions

This chapter summarises the salient findings of our research and highlights the potential implications for education. It includes survey findings, learnings from the development and trials of D&T units, and aspects of design and cognition studied through students' design productions and their engagement in the making activities. Research implications and possibilities of future research are integrated with the discussion and findings. Implications for education in general and technology education in particular are discussed towards the end of the chapter.

This research is developmental exploratory in nature. The findings from the study are organised and discussed in terms of the following three sub-heads:

- Insights on students' ideas about technology
- Insights from development and trials of D&T units
- Cognitive aspects of students' design

6.1 Insights on students' ideas about technology

Understanding students' ideas is a key step towards meaningful learning. Perception and attitudinal studies in education help explore crucial aspect of an issue, concept or an idea. Technology education is a construct little explored in the Indian school context. This section reports the salient aspects of the development of an instrument to learn students' attitudes to technology as well as the findings of the study.

An appropriate instrument that integrates questions on local contexts and encompasses the several manifestations of technology was needed to probe students' ideas. Developing a questionnaire appropriate for the Indian middle school students involved drawing insights from an earlier study on students' depictions of images of technology in the form of posters, a medium for open expression of ideas. These insights were integrated with the philosophical understanding of technology in terms of its manifestations: technology as objects, activities, knowledge and volition, drawn from literature. The questionnaire developed was pilot tested, validated and checked for test-retest reliability.

The study involved middle school students (class 8, average age 13 years) in Mumbai and surrounding areas. The sample chosen included: (i) more than one *socio-economic setting* (rural and urban), (ii) the two most commonly encountered *media of formal learning* in the State of Maharashtra, namely, Marathi and English, and (iii) had a near equal representation of both the *sexes*. The study was carried out in two phases: the pilot and the final study. The pilot study involved students from 3 schools that included an urban Marathi, urban English and a rural Marathi medium school. The final study was carried out with 11 different schools in Mumbai and its surrounding regions.

The findings are discussed in terms of the trends in students' responses, followed by a discussion on differences in attitudes in terms of the three variables, namely; settings, medium of learning and sex.

Technology and students' interests

Artefacts and abstract constructs related to thinking such as knowledge, understanding figured most prominently in the list of spontaneous ideas about technology generated by students. Indian middle school students seemed to have a positive attitude towards technology as seen through their responses on several questions: large majority of students felt the need to know and use technology in order to fulfill their future plans, they agreed on the positive consequences of technology and associated positive qualities (e.g. important, useful) to technology and disagreed on statements which stressed the negative effects of technology. Besides, they were convinced that technology is an important ingredient for the advancement of a nation. Students indicated their willingness to engage in design and make activities if provided an appropriate motivation when they preferred to make a toy rather than buy one from the market.

Technology as objects

Students' ratings of objects and activities with respect to technology reflected the criteria that are the basis of their choices. They considered power-driven artefacts (petroleum-run, electric or electronic) as involving *high technology*. These included largely the transport (aeroplane, scooter, etc.) and communication (computers, telephone, etc.) devices. A simple, mechanical device such as a hand-pump was rated as involving less technology than an electric water pump. Sports (hockey stick, carrom board, etc.) and musical (drum, flute, etc.) instruments were rated as involving *no* or *low* technology. Kitchenware was also considered as not involving technology. The role of a temporal aspect is suggested by the different ratings of objects. Students rated simple, mechanical objects (office tools, implements) as *low technology* and the modern age (post-industrial) devices as involving *high technology*.

Locations in which objects were rated as *high technology*, were also those considered technological. Toilet was a location considered as not involving technology while laboratory, factory and railway station were perceived as locations involving technology by a large majority of students. Considerations of technology as *high* or *low* shape our interactions in a technological world. We may limit our understanding to a narrow class of artefacts. Drawing attention to critical aspects of technology in objects considered *low technology* may help students appreciate the intricacies and diversity in product manifestations of technology.

Technology as activities

Like technological objects, students perceived technology to different extent in different kinds of activities. Activities involving some kind of deliberate training for making or handling (e.g. watch repair, wiring electrical connections) were considered as involving *high technology* while household activities (sweeping, making rangoli) were rated as involving *no technology*. Science related activity contexts were considered as involving technology. For example, students most often related science as a school subject related to technology, besides rating laboratory apparatus and laboratory as involving technology.

Technology as knowledge

Relation of technological knowledge takes a prominent place when it is concerned with careers. Students saw occupations such as scientist, computer engineer and doctor as those needing prior technological knowledge. Indian society considers these occupations as involving mental work and being suitable for the "academically bright". Whereas dancer, potter, carpenter were perceived as occupations where prior technology knowledge may not contribute to performance. These occupations involve physical labour. Khanna (2006) in the context of development of design education in India, points out that the arts, crafts and design activities were historically practiced by the so called lower caste communities in India and therefore even today are looked down upon by people. The social value ascribed to occupations and the mental-manual divide dictate the considerations of technological knowledge. Question that pertain to the content of technology deal with knowledges, skills and values that need to be integrated in the learning units. Students' perceptions of certain technology as important or non-essential has major implications for designing learning. A pedagogy is needed that integrates diverse knowledges and skills and that can effectively bridge the mental-manual divide.

Technology as volition

Volition in philosophy refers to the human desire and drive for engaging in technology. In terms of attitude towards technology, it refers to the qualities and consequences attributed to technology. Students ascribe all positive qualities to technology such as important, useful, etc. and disagree with its negative qualities such as unimportant, boring, etc. Similar to the trend on qualities, students responded in an affirmative for all statements on the positive effects of technology such as using technology gets work done faster, technology helps countries progress, increases comfort and registered their disgreement on the negative effects such as technology makes our country dependent, makes rich richer and poor poorer. Students responses indicated a positive embrace of novel technologies, be it at the level of individual or society. They adopted a cautious approach to a newly introduced technology and advised testing and trials. However, they were never totally averse to a new technology.

6.1.1 Urban-Rural differences

Of the three variables, influence of the settings seemed to be dominant. Though students rated petroleum derived fuels as involving *high-techology*, the only exception was lantern. One plausible reason may be that lantern is seen as substitute for electric devices when there is a power failure and one associates it with rural locales. A significant number of rural students did not see airport as a locale involving technology, though aeroplane as an object was considered to be involving *high technology*. The response trends indicated that students' rating of objects and locations are determined by the local contexts and exposure to technologies.

Even in the ratings of activities the influence of this variable was evident. Construction or making activity is at the heart of all technological activities. *Constructing a house* had a lower mean value for the rural students than the urban students. Rural students live in houses often build by the family with the help of local personnel and materials. On the other hand, urban students mostly lived in multi-storeyed buildings, see professionals like architects, engineers and semi-skilled masons using modern equipment and materials. They rated *constructing a house* as *high technology*. It was interesting to note the relation between students rating on objects and activities using the same objects. The differential exposure of students to technological activities point to the need to make a careful selection of activities for engaging students in different settings. The rural students perceived the profession of a teacher to be affected by prior technological knowledge more than the urban students. Differences in perception of technology for achieving stated goals reflected the influence of socio-economic settings. Significantly more proportion of rural than the urban students felt that technology was very much needed for achieving the goals of food for all and bringing peace in the world. Besides, the perception of possession of a technologically advanced nation also differed. Urban students had modern industries and nuclear plants as their priority while rural students considered food for all, modern agricultural tools as the essentials. Students' considerations of technological advancement seemed to be shaped by their local contexts and immediate dependencies.

6.1.2 English - Marathi differences

Not many differences in attitudes to technology could be attributed exclusively to the medium of learning. This is because differences on the setting variable (urban and rural), were found to be more influential. The Marathi group, which is a mix of urban Marathi and rural Marathi conceals the differences between urban and rural samples. However, there were a few notable differences.

A significant proportion of Marathi sample rated making wicks as involving *low* technology. *Making wicks* is a practice of rolling cotton into thin structures used in lamps, common in rural households, which children often learn from watching and working with their mothers and grandmothers. The English students did not see technology in this activity.

A significant number of English students felt that the job of a secretary and teacher is more suitable for a girl, while the Marathi students felt that either a girl or a boy can pursue the job. The English students were divided in their opinion about the two qualities of technology, viz; dangerous and easy, as indicated by an equal proportion relating technology and these contrasting qualities. The English sample disagreed that technology causes loss of values and that it has destroyed the crafts while the Marathi sample were unsure of this implication of technology.

6.1.3 Gender aspects

Gender aspects studied were of two types: (1) Differences in responses to the questionnaire from the girls and boys in the rural-urban settings, and English-Marathi medium; and (2) Activities and occupations that were rated as suitable for boys only, for girls only or for both.

Boys and girls had similar ratings for most objects indicating more similarity than differences. 'Home' was perceived as a location involving technology by a significantly greater number of girls than boys. The household activities such as sweeping, washing dishes, making *rangoli* (decorative patterns on house floors) were perceived as involving *no technology*. In the Indian context, these activities are usually done by girls.

Occupations advised to a friend reflected the traditional sex-role biases. It was found that students across all samples considered nurse, cook and dancer as occupations suitable exclusively for a girl. They considered occupations such as carpenter, soldier, mechanic, potter, mill worker and shopkeeper as exclusively for boys. Doctor, TV news reporter, teacher, artist and scientist were occupation perceived as suitable for both, boys as well as girls.

Situational contexts were used to study the influence of the gender aspect on assignment of listed jobs. In general, outdoor and technical activities were seen as suitable for boys while indoor activities were assigned to girls. Such traditional sex-role stereotypes exist and influence students' perceptions. One needs to be aware of the stereotypes and biases associated with technological activities so that they can be challenged by integrating suitable measures into classroom practices. It is important to note that these sex-role biases were held by both girls and boys, who were more similar than dissimilar in their responses.

These insights from the study would help in taking initiatives towards a technology education curricula that would challenge the existing stereotypes and provide opportunities for integrating knowledge and skills from diverse domains of human understanding.

6.2 Insights from development and trials of D&T units

Taking a lead from the exploration of students' ideas about technology, attmpts were made to develop D&T units suitable for urban and rural middle school students. The development of Design and Technology (D&T) education units was an iterative one.

Insights gained from the trial of the first unit in the first setting led to modifications and refinement in the subsequent trials. Thus, development of units was a continuous process of feedback and modifications.

The choice of sample for the study was guided by three concerns, similar to those in our survey study. The sample chosen included students from urban and rural settings with Marathi or English as the medium of formal learning, and had a near equal representation of both the *sexes*. About 20-25 class 6 students (average age 11 years), who were average in their academic performance were selected from 3 schools in Mumbai and its suburbs. The school students who participated for the study were from an urban English medium, urban Marathi medium and rural (tribal) Marathi medium schools. The urban schools being in close proxmity to our Centre, trials of the D&T units were carried out at our Centre after the school hours. The trials with the rural students were conducted in the school hours in their school. The language of instruction used by researchers was same as their medium of formal learning. However, students were free to interact in the language they felt most comfortable. The trials were conducted between August 2003 and September 2003. Each unit involved 15 hours of interaction spread over a period of 3 to 5 days, which varied as per the convenience of students in each setting.

The development and trials of D&T education units draw ideas from the theoretical tradition of socio-cultural theories of Vygotsky and ideas of situated learning which empahsize the role of context in learning, creating and sharing meaning through collaborative engagements. Besides, cognitive processes are seen to emerge through the mediation of tools or artefacts (symbolic such as languages, visuals; and material such as axes, needles) in contexts of interaction as reiterated in the notion of technology stance by Rowell (2004). The units developed draw inspiration from the Assessment of Performance Unit (APU) model for teaching technology to students from primary through the secondary level in schools in UK (Kimbell et al. 1996).

The three units developed and field tested were:

1. Designing and making a bag to carry five books
2. Designing and making a windmill model to lift the given weights
3. Designing and making a puppet and staging a puppet-show

Insights from literature were organised in terms of the aspects, which guided the development of units. The six aspects were: students' perceptions, content of technology, aspects of teaching learning and classroom interactions, classroom resources, cognitive aspects and issues of evaluation and assessment.

Aspects of complexity and familiarity were taken into account while thinking of the D&T units. The units tried involved a sequenced starting from simple, familar product to complex artefacts involving diverse levels of collaborative interactions. This was coupled with researchers themselves trying out several ideas, exploring the possibilities and checking the feasibility through designing and making. Thus, the process of developing a D&T unit was a design process in itself!

The choice of the units from among those listed also included the content of the unit, judged by taking into account the pre-requisites needed for each unit. The knowledge (conceptual) content and the procedural and skill content that each of the units conveyed was analysed. Aspects of cognition needed to be accessed for analysis. A variety of data sources were generated by building into the units scope for negotiating and exploring design ideas through a variety of design productions, encouraging written descriptions in form of poems and write-ups, building in communication of design and product and evaluation of students' products. All paper-pencil productions were maintained in a group portfolio. Conscious efforts were made to integrate scope for individual as well as group work.

Through the trials emerged a pedagogical model for teaching technology education at the middle school level for the Indian context. The model referred to as *Collaboration and communication centred model* involves activities such as, Motivation and investigation, Design exploration, Technical drawings, Plan for making, Communication of design and plan, Making, and Evaluation and Reflection.

The process of design of the units demonstrates that learning is a dynamic process involving adaptation to the contexts and continuous refinement in order to account for the needs and demands of the situation. Making a unit an authentic learning experience calls for efforts on part of the teachers in selecting contextually valid design problems, channelling the open-ended discussions, integrating and valuing diverse expressions and initiating critical discussions. D&T units encourages students to visualise the structure and material aspects of their design and communicate to others their visualised design and anticipated making. The units challenge students and encourage them to move beyond just want they know to imagine and construct their ideas and see how they could get actualised. Students journey from analysing the problem, visualisng solutions to generating a feasible solution requires students to invest and hone several kinds of knowledge and skills. The D&T units encouraged expression of ideas through a variety of modes including visuals, models, design productions, gestures and actual products. D&T education units that take into account these features can be an enriching experience for both teachers as well as students.

6.3 Analysis of design and cognition

Aspects of design and cognition lie at the heart of teaching-learning practices but have received little attention. Studying cognitive aspects of design may help answer some of the issues concerning structuring of units and integrating content and assessment in ways that the D&T units are no longer seen as a taxing ritual but become productive in terms of the gains by the learners. This study analysed students' design productions and classroom observations which were the daily records of the trials, for the cognitive aspects in a D&T engagement. Analysis was supported by other data records such as the audio-video, writings and evaluation sheets of students.

Students' design productions, served as a window to the group's journey of visualising and exploring design ideas through to its making. They provide evidences for the cognitive processes in the D&T units. The students productions include: *exploratory sketches*, generated during the goup's exploration of potential design ideas; *technical drawings*, which give detail of the artefact or system conceived with estimates of dimensions and materials required; and *procedural map*, which involve a step-by-step plan of actual making. It is thus an encapsulation of the anticipated making. While these productions are influenced by contexts, they can still be compared across contexts. These productions aid the understanding of how students' ideas evolved through the three units and over time. The evidences suggest the richness of cognitive activities occuring during the trials of D&T units.

Analysis of classroom observations revealed evidences for the influence of students' perceptions of materials in their designs. These perception included students' ideas about materials and their properties, reasons for costing and stereotypes associated with people and their activities. The classroom engagement during the discussion of context and investigation of materials suggested that there was scope for integrating concepts and skills gained through a range of personal experiences of students. Besides, exploring contexts and structural and functional properties of related artefacts, students could express and share their ideas. Through this interactions, they could build on their vocabulary and hone their skills of communication and negotiation. As students explored the structural and functional aspects, they practiced their skills of estimation and measurement, quite often learning from their failures. For example, students often did not leave margins of cloth for folding the ends of their bag or puppet, and realised the error later in the making.

The urban students were given a session on technical drawing to expose them to the skills and conventions of a technical drawing so that they could better explicate their visualised design through drawings. The rural students who were very shy, often covered their faces with files and very less open in the first unit. Realising this, we integrated a "make-up session" just before the second unit. The session included games and activities that enriched students on aspects of technical drawings, measurement, skills of folding and sewing, and also their communication skills. D&T units thus served as contexts for enriching vocabulary and mediated integration of knowledge from diverse domains.

The analysis of students' design productions gave valuable insights about students' cognitive activities. The productions suggest that students were competent in handling structural-functional issues and could represent and express their ideas through diverse means. Groups visualized the desired artefacts using the verbal as well as the non-verbal modes (gestures, exploratory sketches, signs). Students tended to use exploratory sketches that were tentative in nature and served as a means for communication, collaborative interaction and externalisation of their visualised designs. Students in groups interacted with their explorations and transformed and refined their ideas to arrive at a feasible and acceptable design for their group. It was noted that the complexity and familiarity of the anticipated artefact dictated the extent of explorations made by students. Design of complex and unfamiliar artefacts generated more explorations. Students used diverse graphicacy skills and strategies to detail their design. They adopted a particular perspective for bringing out maximum details in their drawings. A lateral perspective was often noted in the unit on windmill model while they tended to use a lateral and frontal perspective for the unit on bag and puppetry. Often students used graphical symbols such as repeated lines to demarcate a structure for the rest of explorations or to indicate motion or a structure while making exploring their designs. They used icons to depict materials for joining, cutting actions, and even depicted tools (scissors, hammers) in their procedural maps.

Students used the strategy of X-ray drawings to depict assemblies in objects. X-ray drawings are depictions which show objects passing through each other as if the material is transparent. The unit on windmill model involving complex objects and assembled parts had more X-ray drawing than any other unit. At times, students used selective abstractions, which implies reducing some materials to icons in order to facilitate elaboration of other aspects of the assembly. For example the tower poles and vanes were depicted by a group as simple lines in order to get an idea of assembly and the functioning. Some students included enlarged views to zoom-in on parts of an object to highlight structural details of components.

Students used gestures, concrete objects and models to visualise and communicate their ideas. Problems in making estimates and representing dimensions and units surfaced in their struggle to depict these aspects in their technical drawing. They could successfully overcome the hurdle in depicting dimensions and estimated lengths once given an exposure to techncal drawings. Their skills of estimations improved through practice. Issues of assemblies, joints and reinforcement though addressed in explorations was not concretized until the stage of making. Quite often groups had to modify their designs to give stability to the product and prevent it from wear and tear. These realisation came about while making the artefacts.

Evidences for visuo-spatial thinking were noted in students productions. Some students tessellated the sides of tower poles so that they could economise on the material resource used for making. Students used concrete materials to make visual analogies and communicate their design ideas among group members. Evidence for a conceptual analogy was noted in one of the groups, where the idea of a star shaped structure evolved into a vane structure for their windmill. Designs were found to be shaped by socio-cultural influences which played a role in the generation of ideas, choice of materials, and resources used.

Students engaged in exploration and modification of materials, and discussed properties and functions right from the conceptualisation phase through making to reflecting. They refined their design ideas in the making as well as evaluation phases suggesting that designing pervaded all phases of the *communication and collaboration centred model* for teaching-learning of design and technology.

Technology is experienced! Technologies necessarily involve action and need to be practised. Well tailored technological practices that take into account students' perceptions and attitudes towards technology can enrich help tailor D&T units to appeal to students from different contexts and linguistic backgrounds. Design and technology education units can offer learning opportunities which may help students get a real-life exposure to engaging in technological practices.

6.4 Limitations of our study

Although the study gave valuable insights about the benefits of engaging students in design and technology education, it was largely exploratory. It covered a breadth of issues, some of which are leads for further research.

Some of the limiatations were with respect to students' productions. A few students erased their explorations and redrew over the earlier sketches, which limited our access to their original design ideas. Some of these were inferred from recordings. The audio-visual data collection was at times too limited due to non-availability of resources such as electricity. The study could have benefited from having better or more suitable resources.

The explorations suggest several possible areas of study. These include studies of the role of gestures in designing and making activities among naïve designers, the influence of visual and conceptual analogies in design and the influence of prior exposure to mechanisms and principles in design. Assessment of students' activities, especially of collaborative work is a critical and difficult aspect of introducing D&T as a school subject, and needs to be studied.

As compared to an entire classroom in a school, only a subset participated in the study carried out by reseachers' team. The units need to be tested in a full-size classroom with one or two teachers. The teacher professional background that will best facilitate D&T education needs to be probed. In addition, a study of naïve, novice and expert designers will help understand the cognitive aspects of design better.

6.5 Implications for education

Inclusion of technology education as a part of general education has a two-fold value: (1) contributing to other subjects, and (2) for technology education as a discipline in its own right. Both these issues are discussed below.

Implications for education of existing school subjects

D&T education is transdisciplinary. It draws knowledge and skills from several disciplines and at the same time provides an authentic context for integration of disciplines. Aspects of imagery and visualisation, as well as the use of non-verbal modes of thinking have been studied. These need to be integrated in classroom discourse.

Many atimes it is argued that there is a gap between school learning and real-life situations. D&T units involve understanding the problem situation with its constraints. Such a natural outlook towards learning recontextualises the learning in schools.

The pedagogical model for teaching D&T units places a high value on motivation and investigation aspects, which are are often considered to be very elusive. However, the context of D&T engages students to think reflectively about materials and properties, structure and functions, and even relate these to their everyday experiences. Drawing such linkages is crucial to contextualising activities. The D&T units provide an exemplar of how teaching can become an enriched and interactive experience.

Our research investigation aims at integrating investigating, designing, planning, making and reflecting. These attributes lie at the interface of design and cognition through activities for active engagment of Indian middle school students. With the focus on designing and collaborative work, students can acquire a variety of skills that could equip them to face real life challenges, develop habits of critical inquiry and empower themselves to visualize alternate ways of transforming the material world around us.

After making, the groups tested their products, to check if it satisfied the purpose for which it was designed. The research suggests that peer evaluation in groups can serve as means for assessment. Students' reflective thoughts on change in design and the finished product gave clues to the fact that student could think reflectively on their ideas and actions.

Of all things, D&T units can challenge the existing dualities bridge the divide between the mental and the manual, the product and the process, teacher and the students, ideas and expression!

Insights for technology education

The study offers valuable insights to field of research in technology education. As a socio-cultural context with diverse languages, cultural lifestyles and a fusion of wide range of technologies, India presents itself as a unique context for trying and testing D&T units. A model suitable in such a context can have wide ranging applications and the learnings contribute not only in refining ideas about conducting trials but also adds to our understanding of technology.

Besides, the study is an initiative which demonstrates the feasibility of encouraging young minds to engage and think about the technological world around in such a way that they develop creative and novel ways of addressing real-life problems. Students engagement in D&T education units can help develop a critical eye for issues and concerns that surround the development and working of a product/system and the factors that govern its functioning. Through a collaborative mode of working, the units offer opportunities for students to work together towards a common goal. Skills of communication also get honed through their interactions which relies on multiple modes of expression. One important benefit is that D&T units structured in such a way mediate interaction between thought (cognitive activity) and action (manipulative activity).

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A Survey instrument: English version

Homi Bhabha Centre for Science Education
Tata Institute of Fundamental Research
V.N.Purav Marg, Mankhurd
MUMBAI

Instructions for students

Homi Bhabha Centre for Science Education (TIFR), Mumbai, conducts research in education and students' ideas about science. We would like to know your views about technology. In this questionnaire, you will find questions about:

1. Yourself
2. Your ideas of technology
3. Your interests in technology
4. Links between occupation and technology

Technology according to some is, "The art or science of applying scientific knowledge to practical problems."

You may not know the details of some activities and objects used in this questionnaire. Yet, you must have heard about them or might have come across the words. We would like to know what you feel or what ideas you associate with these objects and activities.

There are no 'right' or 'wrong' answers! Your answers should be the ones that you think are right for you. That will help us to understand how technology is relevant to you.

Please note that this questionnaire is not a test and there are no grades or marks involved.

Your responses will be kept confidential.
Thank you.

Swati Mehrotra
Ritesh Khunyakari

I **Questions about yourself**

1. Name:____

2. Class:____

3. School:____

4. Medium of Instruction:________________________________

5. Age: ___________Years 6. Male ☐ Female ☐

7. Date of birth (if known): Please write in the boxes given below in the same way as explained by the example.
For Example: Abida's birth date is 9 July 1985, that is 9-7-1985
She will fill the boxes like this–

9	7	1985

Now, write your birth date in the boxes given below

		19

8. After completing school education what do you plan to do?

____

____

____

____

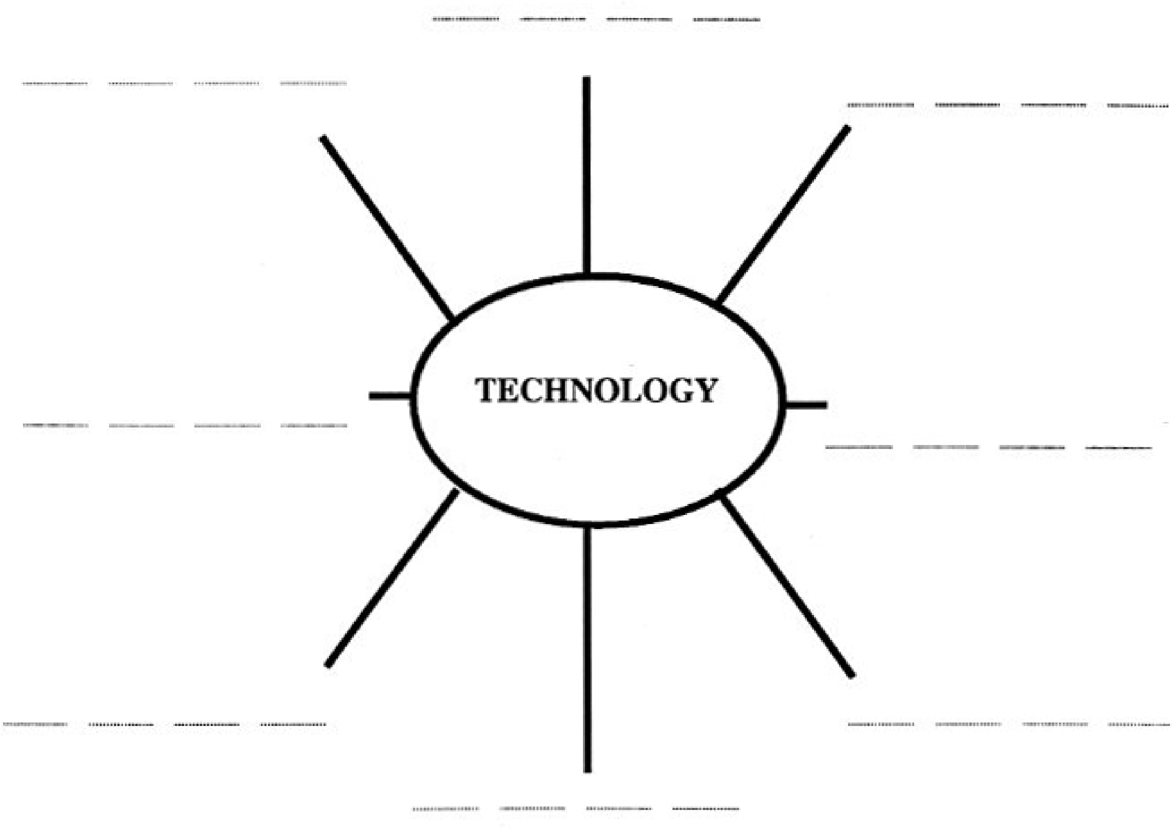
9. In order to fulfill your future plans,
(Tick (√) ***only one*** box for each of the following)

1. Do you think you need to know technology? Yes ☐ No ☐

2. Do you think you need to use technology? Yes ☐ No ☐

II Ideas about technology

1. What comes to your mind when you see/hear the word technology?
   Write on the dotted lines the words that you relate to technology.



III Technology in activities

What kind of technology is involved in the following activities (things we do)? Tick (√) ***only one*** cell in each row.

No.	Things we do	No Technology	Low Technology	High Technology
1	Playing games			
2	Making pickles			
3	Painting the wall			
4	Making clay toys			
5	Cooking			
6	Weaving cloth			
7	Making rangoli			
8	Washing dishes			
9	Arranging flowers in a vase			
10	Drawing water from a well			
11	Applying mehendi (henna)			
12	Repairing watches			
13	Writing letters			
14	Making wicks (for lamps)			
15	Polishing shoes			
16	Sweeping			
17	Guarding the borders of the country			
18	Constructing a house			
19	Fishing			
20	Plumbing activities (fixing a leaking tap)			
21	Welding car parts			

No.	Things we do	No Technology	Low Technology	High Technology
22	Making chappatis			
23	Tanning leather			
24	Making candles			
25	Tailoring			
26	Making fire crackers			
27	Making bangles			
28	Driving vehicles			
29	Acting in a drama			
30	Wiring electrical connections in a house			
31	Making "veni" *(gajra)*			
32	Drawing water using an electric pump			
33	Repairing punctures			
34	Filling ink pens			
35	Packing biscuits			

IV Choose an occupation

Two of your friends, a girl and a boy, come to you for your advice on which occupation they should choose. Which occupation would you advise them to choose? Put a tick (√) in the suitable column of your choice against each career.

No.	Occupations	Girl	Boy
1	Artist		
2	Dancer		
3	Farmer		
4	Vegetable seller		
5	Potter		
6	Scientist		
7	Doctor		
8	Secretary		
9	Nurse		
10	Computer engineer		
11	Teacher		
12	Soldier		
13	Shopkeeper		
14	Mill worker		
15	Dentist		
16	TV news reporter		
17	Cook		
18	Mechanic		
19	Pilot		
20	Carpenter		

V Effects of technology

The table lists some statements about technology. Against each statement, indicate whether you "agree" or "disagree" or are "unsure". For example: for the statement **Technology causes change,** if you agree with this statement then you would tick the "**Agree**" column, if you do not agree with the statement then you would tick in the "**Disagree**" column and if you are not sure then you would tick the "**Unsure**" column. Tick (√) ***only one*** box.

No.	Statement	Agree	Unsure	Disagree
1	Using technology gets work done faster			
2	Technology leads to pollution			
3	Technology makes our country depend on others			
4	Technology increases chances of employment			
5	Maintenance costs of technology are high			
6	Effective use of technology increases wealth			
7	Technology increases comfort			
8	Technology leads to unemployment			
9	Technology helps countries progress			
10	Technology supports creativity			
11	Technology makes the rich richer and the poor poorer			
12	Technology brings people together			
13	Technology destroys the crafts (e.g. handicrafts)			
14	Technology helps remove poverty			
15	Technology causes a loss of values			

VI Locating technology

Do you think that technology is used in the following places? Please tick (√) ***only one*** in each case.

No.	Location	Yes	Don't know	No
1	Home			
2	Airport			
3	Farm			
4	Railway station			
5	School			
6	Post-office			
7	Factory			
8	Laboratory			
9	Bank			
10	Coal mine			
11	Toilet			
12	Cinema hall			
13	Market			
14	Bus depot			
15	Fair *(Mela)*			

VII Interests in technology

This section explores your interests in technology. Please tick (√) if the statement applies to you. If it does not apply to you then put a cross (X) in the box.

1. At school I discuss about technology................................ ☐
2. I like reading technology related articles............................. ☐
3. I like making things myself.. ☐
4. I would like to choose a career/ job that is related to technology.. ☐
5. I discuss technology with my friends outside school............... ☐
6. I watch/ listen to the T.V/ radio programmes on technology...... ☐