COGNITION IN ACTION IN DESIGN AND TECHNOLOGY UNITS AMONG MIDDLE SCHOOL STUDENTS

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In technology education, designing and making are often discussed as two distinct entities. However, design is the core of technological activities. Design pervades all the phases including making, of Design and Technology (D&T) education units that we have developed for middle school level. We conducted trials of these among school students in three socio-cultural settings. This paper attempts to highlight the link between students' conceptualization of a plausible solution, namely designing and its actualization as artefact. The links are exemplified by our observations of students in one D&T unit on making a windmill model to lift given weights. The paper also suggests a framework for analysing the cognitive aspects involved while students collaboratively made an artifact designed by them.

INTRODUCTION

Technology education or education about the world of artefacts has been incorporated in school curricula in many countries across the world. It variously implies technological literacy, skills for the world of work, applications of science, design and engineering, etc. In some countries, it is taught as design and technology (D&T), which includes visualisation, manipulation and use of material resources and tools in order to solve problems.

COGNITION AND D&T

There has been considerable research in D&T education on school students from pre-primary to secondary school levels (Solomon & Hall, 1996; Owen-Jackson, 2002). Kimbell et al (Layton, 1993) have emphasized the dialectic interaction between the mind and the hand. Reflection-in-action in design activities that involves a conversation with tools and materials has been noted by Schön (1983). Dewey (1991) distinguishes "reflective thought" from colloquial connotations of thought and emphasizes its role in learning.

Research studies have used drawings and interviews to understand children's ideas of objects, their structure and functions. Senesi (2000) studied individual 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.

The cognitive benefits of introducing a D&T component in the Indian school curricula have yet not been established. Hence, it is essential to probe the cognitive as well as other implications of D&T in Indian schools. The study presented here is part of a project on the development and trials of three D&T units: making a bag to carry a few books, making a windmill model that can lift given weights and making puppets and staging a puppet show. During the trials, students engaged in a

sequence of activities like investigating, designing, planning to make, making and evaluating interspersed with structured communication. Design is the core of D&T units and pervades all activities within it. The cognitive aspects during the designing stage have been reported elsewhere (Khunyakari et al, in press). This paper focuses on the cognitive issues that arise in the making of a windmill model, which the students have already conceptualised through the designing activities.

METHODOLOGY

The sample for the study involved about 20-25 students of Grade 6 (age 11 to 14 years) from each of three distinct socio-cultural settings: an urban Marathi medium school, an urban English medium school and a rural school. The students, who volunteered to be a part of the study, included near equal proportion of boys and girls.

The unit on making a windmill model involved several tasks. Students from each socio-cultural setting worked in groups of 3-4 members, all boys, all girls or mixed sex groups, over 15 hours spread across 5 days. The groups investigated the problem, explored potential solutions through sketches, made technical drawings, listed the required materials, and drew up a plan for making (procedural map). They made the product they had designed and evaluated their own and others' products. It is the making phase that we consider here. Figure 1 illustrates the different aspects in designing and making a product (or artefact), which is the goal of the D&T unit.

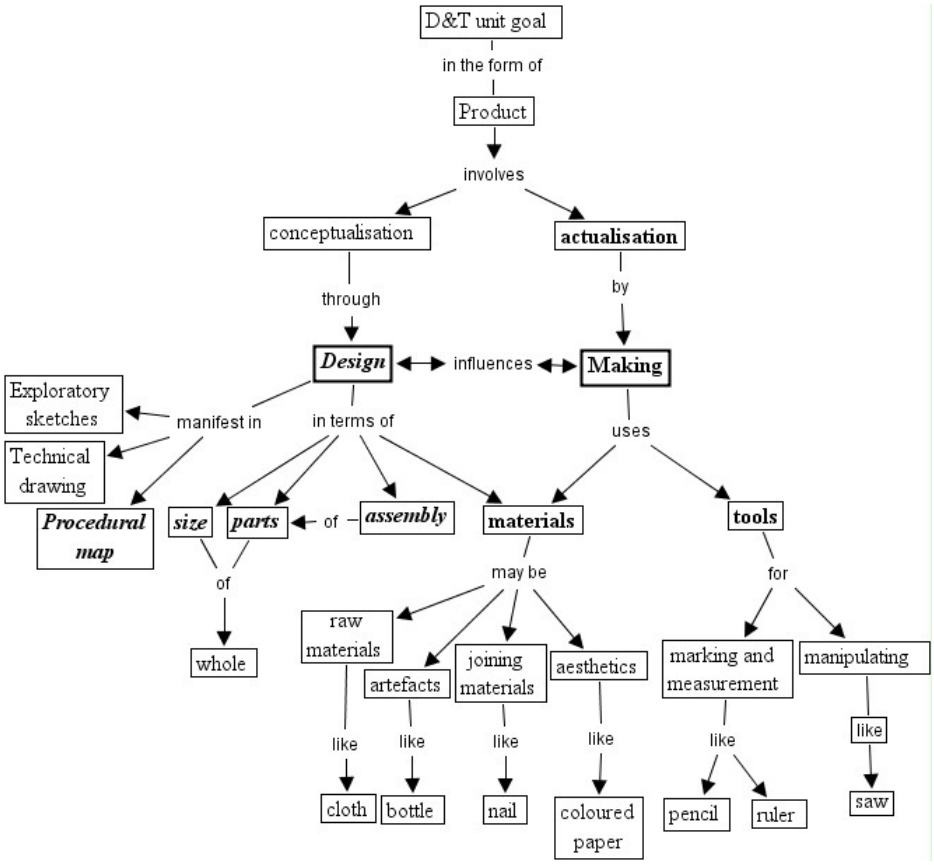


Figure 1: Different aspects in designing and making a product to solve a problem

OBJECTIVES OF OUR STUDY

The paper aims to characterize the cognitive activities of students as they worked in a collaborative learning environment during the making phase in a prototypical D&T unit (bold in Figure 1), and the nature of design changes while going from designing to making the artefact (bold and italics in Figure 1).

FRAMEWORK FOR ANALYSIS

In contrast to studies with individual designers, this study involves students collaborating to design and make a product in a D&T unit. Several cognitive aspects characterise the making of an artefact in a D&T unit. In this study we have focused on (i) visualisation of the artefact to be designed including its parts and assembly, (ii) application of knowledge of material properties and processes, (iii) exploration of tools and their use, (iv) strategies for revealing and solving problems, and (v) evidences of formulation and development of design inferred from students reference to design productions. The first four cognitive aspects are relevant in both individual and collaborative work. The collaborative environment affords a unique opportunity to study the aspects of formulation and development of design among naïve designers.

Design influences and is influenced by the making activity (see Figure 1). However, the paper and pencil design productions, all prior to making, include exploratory sketches, technical drawing with dimensions shown, and a multi-step plan of anticipated making (the procedural map). This study uses the procedural map for comparison with the artefact because: (1) it marks the end of design conceptualisation, (2) indicates students' preparation for making, and (3) includes illustrations and verbal descriptions of steps in anticipated making.

References to changes in design ideas while making are obtained from vignettes, audio-visual data and researchers' logs. The analysis considers the following changes from design to actual making:

- Size and shape of the artefact
- The 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
- Joint types and joining materials planned and used

COGNITION IN MAKING A DESIGNED ARTEFACT

Design ideas evolved beyond students' design productions during the making of the artefact in all socio-cultural settings. The differences between design productions and the finished product varied among groups. The cognitive aspects involved in making are discussed below.

Visualisation

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 2, 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 3). 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.

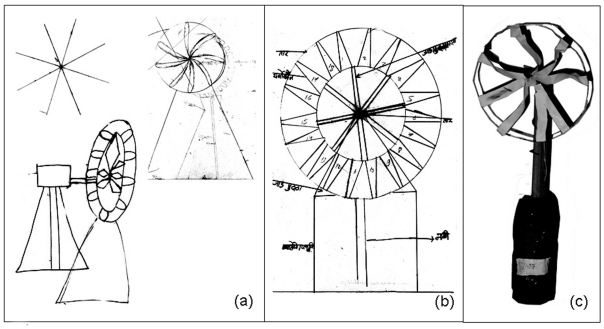
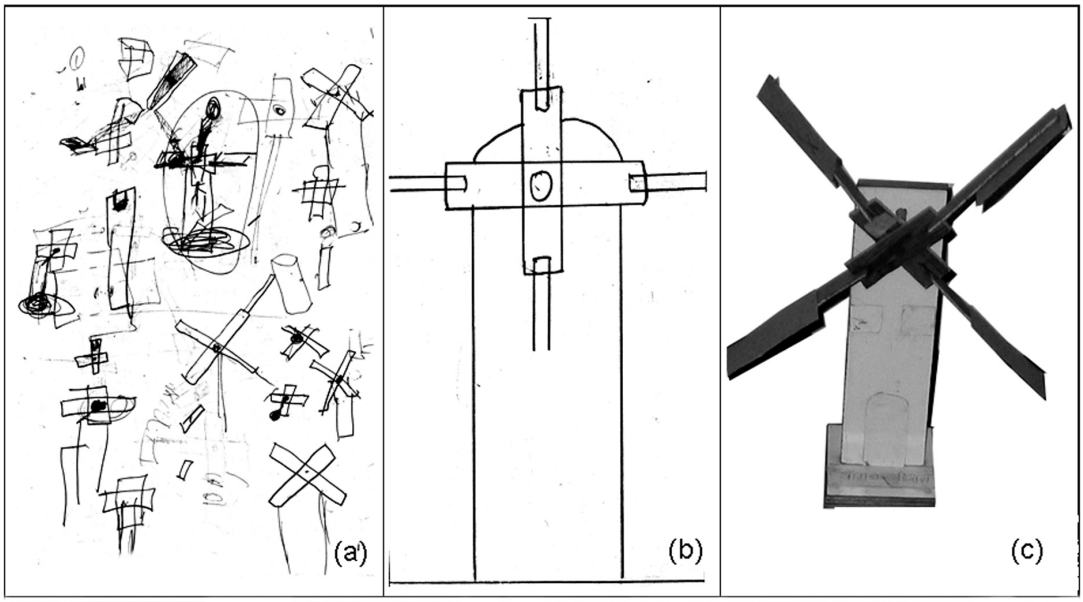


Figure 2: Redesigning of joints and assemblies while making by an urban Marathi group: (a)



explorations, (b) final step of procedural map, and (c) the windmill model.

Figure 3: Similarity between design and product in an urban Marathi group: (a) explorations, (b) final step of procedural map, and (b) the windmill model.

Knowledge and application of material properties

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.

Exploration 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 suggested to 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.

Strategies for revealing and solving problems while making

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.

Contribution 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. Most students did not refer to their design productions. Yet there were significant similarities between their design productions and their finished product. This indicates that, once explored and conceptualized, the design remains in the shared domain of fellow designers and makers. Some groups, however, referred to their design productions while making.

CONCLUSION

The D&T unit offered opportunities for collaboration in the shared use of ideas, material resources and tools, and mutual help. The study found evidences of formulation and development of design.

Student designers collaborated in the designing and making activities. Characteristics of the collaborative work are also revealed by vignettes in the way students anticipated each other's moves and assisted each other. Communication issues relevant to the collaborative working mode are addressed in another paper on students' oral communication (Mehrotra et al, 2006).

Several cognitive aspects characterise the making activity in a D&T unit carried out in a collaborative environment. They include those that characterise individual design and make activities as well: visualisation of the artefact to be designed including its parts and assembly, application of knowledge of material properties and processes, exploration of tools and their use, strategies for revealing and solving problems. These have been exemplified in this paper.

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