A Study Exploring the Strategies Utilised by Indian Middle-School Students in Identifying Unfamiliar Artefacts

Farhat Ara, Chitra Natarajan, Sugra Chunawala

Homi Bhabha Centre for Science Education, Tata Institute of Fundamental Research

Abstract

This paper presents the strategies employed by Indian middle-school students working in groups to identify three unfamiliar artefacts. The activity described in this paper was aimed at sensitising students to the close link between form and function and to bring a certain amount of uncertainty in the tasks before the actual design task. It was part of a larger study (Ara et al 2009) that explored students' ideas about design and designers before and after they engaged in design related activities. Twenty two students of class 7 worked in six groups of three or four members and the entire exchange was video-recorded. The verbatim transcription of the conversation within the groups and the actions and gestures executed by students were categorised. Groups came up with various accidental functions for the three artefacts and only three groups were successful in identifying the intended functions of all three artefacts. All groups utilised similar strategies while trying to identify the artefacts however they differed in the frequency of use of these strategies. *Cognitive strategies* included active discussions within the group and *handling strategies* involved manipulation of the artefacts by the group members. Groups which were less interactive, less critical of others ideas and less defensive of their own ideas were unsuccessful in identifying the intended functions of the artefacts.

Key words

accidental functions, affordances, cognitive strategies, handling strategies, Indian middle-school students, unfamiliar artefacts

Introduction

Imagine a hunter-food-gatherer landing in a modern home in a metropolis. How would this individual respond to the vast array of artefacts around? If she got hold of a seemingly simple artefact such as a pencil, she would perhaps appreciate its long and slender body and think of the different ways in which she would make use of the pencil, back in the jungle as in the 1980 English movie "The Gods must be crazy". The purpose of this paper is to describe the strategies employed and the problems encountered by middle school students in identifying the intended functions of three unfamiliar artefacts.

An artefact is an immediate and obvious manifestation of technology (Mitcham 1994). We interact with innumerable artefacts everyday. Ranging widely from stone-age axes to global communication networks, from domesticated plants and animals species to space stations, from cuneiform tablets to universities, and more (Ferré 1995), artefacts have been transformed and have transformed our lives too in the course of time. The transformation of artefacts has been brought about by the conscious and intentional activities of humans, which distinguishes artefacts from 'natural objects' (Vermaas and Houkes 2006).

A philosophical account of artefacts

Artefacts are designed for some purpose and the purpose that it serves is called the artefact's *function*. Artefacts have a dual nature – *physical nature*, having properties such as size, colour, shape, weight, smell etc. and *functional nature* (Kroes 2002, De Vries 2006, Kroes and Meijers 2006). According to De Vries (2006), the physical nature of artefacts exists independent of our intentions but the functional nature is not intrinsic to the artefacts since designers and users ascribe functions to artefacts. So intentions are involved in not only creating the artefacts but also in using them to achieve users' goals.

The designer intends to cause the existence of an artefact which would serve the purpose in hand. In order to do that she might design the artefact with appropriate structure that would allow the realisation of the intended function. The function that was intended by the designer is called the "proper function" of the artefact (De Vries 2006, Vermaas and Houkes 2006). However, users might still identify some other functions that could be performed by the same artefact. These functions which were not intended by the designer are called the "accidental functions." For example, a hammer, used for driving nails into planks, can also be used as a defence against robbers.

Perception of artefacts

How do humans perceive artefacts? While reasoning about artefacts adults seem to adopt what is called the 'design stance' (Dennet 1987 in Matan and Carey 2001), an abstract explanatory schema in which people assume that artefacts are created by a designer with the intention of serving a purpose. 'Design stance' becomes evident in categorisation tasks which show that adults tend to judge an object's category on the basis of (i) its intended function rather than its appearance; e.g. an object that looks like a lampshade but was intended to be used for

protecting against rain is judged to be an umbrella and not lampshade (Rips 1989 in German and Johnson 2002) and (ii) its intended function rather than its accidental function; e.g. an object that was intended to be a watering-can but now used as a teapot was judged to be a watering-can and not teapot (Matan and Carey 2001).

So, when in human cognitive development does the design stance originate? Children rapidly learn about the typical functions of an artefact by observing the adult members of the society (Casler and Kelemen 2005). Some cognitive science researchers believe that children as young as four years can reason about artefacts in terms of design stance (Kelemen 1999). Others argue that it is only after six years that children are capable of making use of design information in categorisation and function tasks (Defeyter and German 2003).

What about artefacts which are unfamiliar to us? How do we know about their intended functions and what to do with them? The intended function of an artefact constrains the artefact's structural properties and its materials. For example, a coffee mug should have a closed bottom, an open top, must be graspable, must not be made of ice etc. (Matan and Carey 2001). Thus the structure of the artefact becomes a clue to its function. In other words, it provides the *affordances* (Gibson 1979/1986) indicating the possible actions that could be performed on/with that artefact. However, an artefact might provide multiple affordances and hence multiple possible actions. For example a pen can afford grasping, writing with, piercing with, playing catch with, etc. In such a situation, therefore, how does one, as a member in a group make decisions about the intended function of the artefact? What strategies would enable one in identifying the intended function of a novel artefact?

The present paper intends to uncover the strategies utilised by middle-school students to identify the intended functions of three artefacts unfamiliar to them. This activity was aimed at sensitising students to issues of design and to make them appreciate that form and function are closely linked. Different forms can be used to achieve the same function; e.g., different kinds of knife sharpeners. On the other hand function affects form since only certain forms are possible to achieve given functions; e.g. only round things roll.

The activity described in this paper is inspired by the classical work of Crismond (2001). His study consisted of strategies employed by naïve, novice and expert designers while investigating unfamiliar and simple mechanical devices and redesigning them. He found that while doing these tasks, non-expert designers' learning was context bound and device specific; they made little connections from their work to key science ideas. However, these tasks did provide opportunities to the naïve and novice designers in exploring and identifying features of the artefacts that could be redesigned and also to integrate their science ideas in learning about and redesigning the artefacts.

The present study carried out with middle school students, not designers, does not involve redesigning and makes no connection to science concepts. The activity described in this paper was part of a larger study (Ara et al 2009) that explored students' ideas about design and designers before and after they engaged in design related activities such as handling familiar artefacts, discussing history of artefacts and designing artefacts (Table 1). The activity of handling unfamiliar artefacts was scheduled between the history and the designing tasks. The aim was to bring a certain amount of uncertainty in the activities through handling of unfamiliar artefacts before the actual design task which is full of uncertainties.

Activity	Aim of the Activity
Handling familiar artefacts	*Introduce students to the structure and function relationships of artefacts*
Discussing history of familiar artefacts	*Encourage students to question the development of the design aspects of artefacts; make them appreciate that artefacts have undergone intentional and purposeful changes*
Handling unfamiliar artefacts	*Sensitise students to the structure and function relationships of artefacts; Introduce uncertainties in the tasks before the actual design*
Designing artefacts	*Provide opportunities to design a solution, in terms of artefacts, for a real world problem*

Table 1. List of activities carried out with middle-school students with their broad aims

A Study Exploring the Strategies Utilised by Indian Middle-School Students in Identifying Unfamiliar Artefacts

		
Object A has a single slot with steel and ceramic wheels; steel for sharpening and ceramic for honing	Object B has 2 slots & a sliding cover; coarse carbide wheels for sharpening (right) and fine ceramic wheels for honing (left)	Object C has a single carbide wheel in between two plastic-supported steel wheels creating two slots for sharpening

Figure 1. Artefacts used in the study

Design and technology education has not yet become a part of the Indian school curriculum. The broad aim of the study was to explore the possibilities of introducing design and technology education at the middle school level. Students were required to work in groups during this activity. Various researchers have indicated the advantages of group work in developing students' problem solving and critical thinking skills through discussion, clarification of ideas, and evaluation of others' ideas (Gokhale 1995, Mehrotra et al 2009).

Research questions

- What strategies do middle school students utilise while identifying the intended functions of unfamiliar artefacts? What are the contributions of individuals working in a group towards the identification?
- How do perceived affordances of artefacts affect the identification of their functions?
- What accidental functions do students identify for the given artefacts?

Methodology

Sample

The student sample was drawn from a school located in the vicinity of the researchers' institution in Mumbai. It consisted of twenty two students (seven girls and fifteen boys) from Class 7 (12-13 years). Students' participation in the activity was voluntary. The medium of instruction in the school and the language used by the researcher was English though the students' home language was any one of the varied different Indian languages. Students were asked to form groups of three or four members. Prior experiences with the dynamics involving mixed sex groups, (Mehrotra et al 2009) led us to request only single sex groups (two girls' and four boys' groups).

Artefacts used in the study

Three types of knife sharpeners were used in the study, labelled as 'A', 'B' and 'C' (Fig.1). The sharpeners were simple with a few or no movable parts and their structures did not give an obvious clue to their functions. Knife sharpeners are not common in Indian kitchens where people usually sharpen knives on steel files, flat ceramic stones or on the edge of any rough surface available. Many people get their knives and scissors sharpened by peddlers using a foot-operated grinding wheel. It was assumed that students were not familiar with these knife sharpeners and this assumption was true of the six groups used in the study. Another group which was initially a part of the study was found to be familiar with the artefacts and hence data from this group was excluded from the analysis.

Procedure and Data Collection

Each group of students was interviewed for about 40 minutes, when they were handed the three knife sharpeners and were asked whether they had seen any of them before. Students were asked to observe the artefacts carefully and suggest the function of each of them. Each student in a group was provided with a questionnaire (Figure 2). Students could discuss among themselves but had to respond to the questionnaire individually. The role of the questionnaire was to enable students in externalising their thoughts and assist them in identifying the functions of the artefacts. Hence responses generated in the questionnaire were not considered as the primary data. However, the transcripts of the videos were matched with the questionnaire responses to avoid any discrepancy. Students were also requested to think-aloud or verbalise their thoughts. The groups were encouraged to speak in English but two groups who chose to speak in Hindi, the Indian national language, were allowed to do so.

Questionnaire

Look carefully at objects A, B & C which are given to you and answer the following questions

1. What materials are these objects made of?
a. Object A: _____

b. Object B: _____

c. Object C: _____

2. What are these objects used for?
a. Object A: _____

b. Object B: _____

c. Object C: _____

3. Are there any similarities:
a. Between Object A & Object B? Yes/ No (Circle one)

b. What is/are the similarities? _____

c. Between Object B & Object C? Yes/ No (Circle one)

d. What is/are the similarities? _____

e. Between Object C & Object A? Yes/ No (Circle one)

f. What is/are the similarities? _____

Figure 2. Questionnaire

The sessions were audio and videotaped and the conversation (both formal and informal) that occurred within the groups was transcribed verbatim. The transcripts also included the description of actions and gestures executed by students and the time taken to perform the actions. The categories identified for the utterances, gestures and actions emerged from the data and to a certain extent were informed by literature (Crismond 2001).

Results

Students of all the groups handled and explored the three knife sharpeners - 'A', 'B' and 'C'. None of the six groups were familiar with any of the three knife sharpeners. Three groups (Groups 1, 2, and 3) could correctly infer the intended functions of the three sharpeners while two of the groups (Groups 5 and 6) were unable to identify the intended functions of even one of the artefacts. Group 4 could identify the intended function of only 'A'. The statements, utterances, gestures and actions which were indicative of any strategy were identified. Several strategies used by the groups were identified and classified into: *cognitive strategies* and *handling strategies*. Each group had one or more dominant strategy/ies. It was observed that all the groups adopted nearly similar strategies but the frequency of use of these differed in groups.

Cognitive strategies

These involved active discussions that took place among group members while identifying the functions of the

Cognitive Strategies	Group 1 (Girls' group)	Group 2 (Girls' group)	Group 3 (Boys' group)	Group 4 (Boys' group)	Group 5 (Boys' group)	Group 6 (Boys' group)	Total
Suggest new idea	62	44	34	59	43	47	289
Question/seek justification	39	8	13	12	5	1	78
Reject ideas	24	5	9	29	5	3	75
Defend Ideas	17	17	4	7	2	0	47
Reiterate ideas	21	6	6	10	6	11	60
Direct others attention	29	16	8	8	27	4	92
Acknowledge ideas	14	8	7	16	4	2	51
Enquire from others	36	17	6	4	16	18	97
Consolidate ideas	5	1	1	3	0	0	10
Use gestures	15	14	12	9	5	9	64
Use similarity idea	Used	Used	Used	Not used	Not used	Not used	---
Total interactions	262	136	100	157	113	95	

Table 2. List of cognitive strategies and their frequency of use by the groups

artefacts. An overview of the frequency of cognitive strategies utilised by each group is indicated in Table 2. 'Suggest new ideas' referred to any new idea suggested by a student in a group about, (i) materials; e.g. Group 1, S3: *"I think this material is stone,"* (ii) structure; e.g. Group 2, S4: *"there is a stone in between the wheels,"* (iii) function; e.g. Group 4, S4: *" 'B' can be used for storing blades,"* (iv) affordances provided by the artefacts; e.g. Group 2, S4: *"…something should enter from this side and come out from the other side,"* (v) actions through which a function would be achieved; e.g. Group 2, S3: *"see, this thing* ('C') *can rotate like this* (shows a rotating action with her hand) *and rub any wood or metal* (vi) possible orientations of the artefacts; e.g. Group 3, S3: *"see, both can be placed horizontally"* and (vii) similarity between the artefacts; e.g. Group 3, S2: *"the metals in 'A' is oriented in this way and the material in B is also placed in this way"*.

It can be seen from Table 2 that almost all groups suggested a fairly large number of ideas (289). The number of ideas suggested was highest for materials (92), followed by functions (52) and affordances provided by the artefacts (40) for all the artefacts across all groups (Table 3). The higher frequency of suggestions for materials could be explained by the nature of the task, where students were asked to identify the materials of the three artefacts, while no such probe was used for the structures of the artefacts.

Sub-categories of "Suggest new idea"							
Material	Structure	Function	Affordance	Action	Orientation	Similarity	Total
92	37	52	40	23	7	38	289

Table 3. Sub-categories of new ideas suggested by the groups

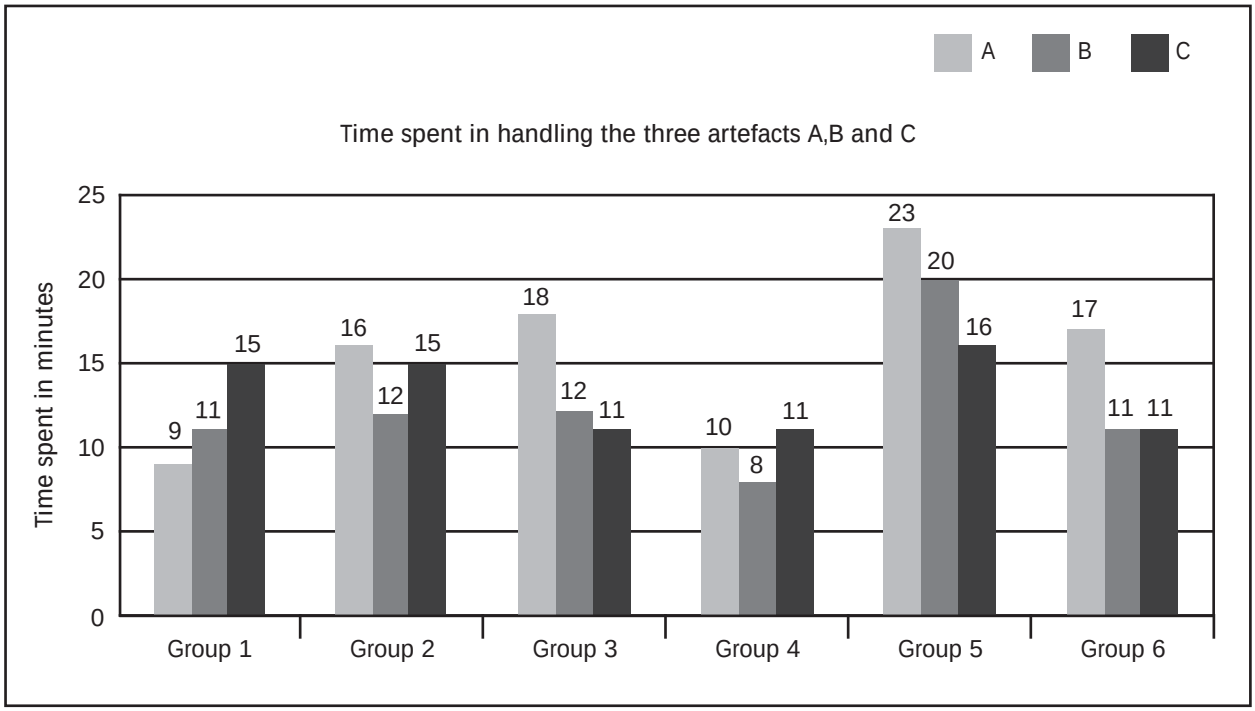
In the category 'question idea/seek justification,' students posed questions to each other or asked for clarification of others' ideas. For example, Group 1, S1: *"How can this be a stone? This is so light."* Students also posed questions to themselves regarding the presence of any structure. For example, Group 1, S2: *"Suppose if 'B' is a knife sharpener then what about these* (pointing to the grooves on the inner side of 'B'). *Why are they there?"* As shown in Table 2, Group 1 posed the largest number of questions (39) to or sought explanation from others in their group followed by Groups 3 (13) and 4 (12), while Group 6 questioned its own members least (1). Groups who did not question the ideas of others but accepted all ideas without objection were unsuccessful in identifying the intended functions of the artefacts. So even though students in Groups 5 and 6 suggested ideas these were not questioned, critiqued nor was any justification sought. This also explains why there were less rejections or defence of ideas in these two groups (Table 2). Both the girls' groups defended their ideas more often than the others and tried to prevent rejection of their ideas.

Students defended their ideas by (i) showing structural evidence; e.g. Group 2, S4: *"'C' can be used for smoothening any metal or wood because of its rough surface"* (ii) showing affordable action; e.g. Group 1, S2: *"Both* ('A' and 'B') *has slits through which knife can be passed and sharpened"* (iii) testing; e.g. Group 3, S3: *"it* (wheels in B's slot) *is sponge."* Saying this, S3 puts his pen refill in the slot of 'B' to check (iv) logical reasoning; e.g. Group 1, S1: *"this* (material in 'C') *is something else. It is so light; if it was a stone it should be at least a bit heavier."* and (v) using analogy; e.g. Group 2, S4: *"see, it* (sharpening material in 'C') *looks like sand paper. Just like sand paper is rubbed on a rough surface to smoothen it, 'C' can also be used for rubbing on wood or metal."*

Students directed attention of others to relevant aspects of artefacts that they were handling, through gestures such as pointing or through words such as "see" (Figure 3). When students directed attention of others, they ensured that others contributed to the identification process. Groups 1, 5 and 2, had directed attention of other members of their groups more often while Group 6 did so least. Gestures were usually made by students to (i) probe the artefact; e.g. gesture of twisting the head of 'A' (ii) direct others attention through pointing (Figure 3) (iii) communicate actions through which a function would be achieved by the artefacts; e.g. drawing hand/pen/finger through the slots of 'A'/ 'B' and (iv) communicate structure of the artefacts; e.g. showing the orientation of wheels in the slot of 'A'/ 'B' with hand. Pointing is a dominant form of gesture when students collaboratively make sketches of routes (Heiser et al 2004). In the present study too, from the video analysis, pointing was found to be prominent among the gestures used by students.

One important strategy utilised by the students of Groups 1, 2 and 3 was in dealing with the question of whether there was any similarity among the three artefacts. For example the most obvious similarities between 'A' and 'B' were the presence of slots and the orientation of wheels within those slots. The obvious similarity between 'B' and 'C' was the sharpening material used. There was no obvious structural similarity between 'C' and 'A'. Both the girls' groups (1 and 2) made use of the above similarities in identifying the function of 'A', 'B' and 'C'. Although other groups did find a few similarities among the three artefacts, these were limited to the material and the superficial appearance of the artefacts.

Figure 3. A student pointing at 'C'



Graph 1. Time spent in handling each sharpener by all the students of each group (in minutes)

Interactions of any kind helped groups in deciphering the functions of artefacts. As depicted in Table 2, Group 6 was the least interactive group (95) and Group 1 was the most interactive (262). In fact Group 1 was successful at identifying the intended functions of the three artefacts while Group 6 was unsuccessful.

Duration of handling artefacts

As shown in Graph 1, Group 4 spent the least time with the artefacts (29 minutes) while Group 5 spent the most time (59 minutes). However the time spent with the artefacts was not indicative of students' success at identifying the artefacts. Group 5 was not able to identify intended functions of any of the artefacts, while Groups 1 and 4, who spent comparatively less time in handling the artefacts were actually successful in identifying the intended function at least one (Group 4) or all (Group 1) of the artefacts.

Handling strategies

These strategies involved handling and manipulation of the artefacts. As shown in Table 4, students used a variety of handling strategies such as observation, probing, trying out possible actions, checking predictions.

"Casual handlings" involved handling the artefacts without looking at their features, while "focused observations" implied looking at the artefacts' features with the purpose of identifying them (Figure 4). The frequency of focussed observation was higher in most groups as compared to casual handlings except in Group 6. While Groups 1 and 2 had higher frequencies of both casual handlings and focussed observations, Group 3 had the least number of casual handlings and comparatively more focussed observations.

What caught the attention of most students in all the groups were the significant functional features of the three artefacts, for example the slots of 'A' and 'B', and the sharpening surface of 'C'. Students probed the three artefacts with anything that was available to them at the

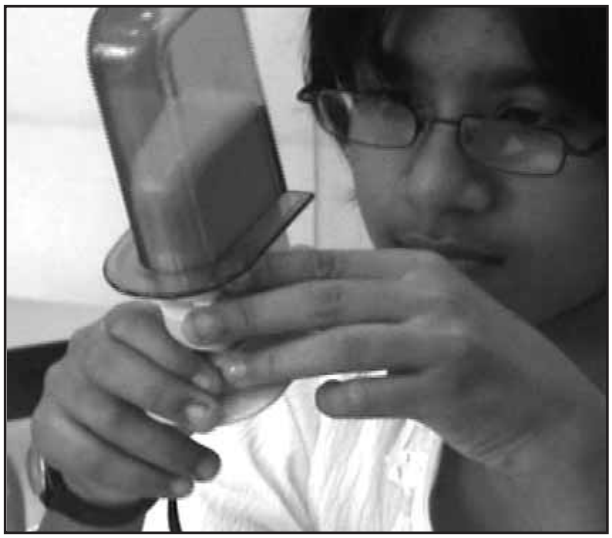


Figure 4. A student observing 'B' closely

RESEARCH

Handling strategies	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
Casual handlings	20	40	11	33	17	21
Focused observations	63	85	50	44	39	16
Probing the artefact with finger/pen/other	7	13	7	7	20	1
Possible actions (orient, tab, shake, rub, press, rolls, rotate)	15	34	22	18	43	17
Checking predictions	6	16	5	2	9	1
Total	111	188	95	104	128	56

Table 4. List of handling strategies and their frequency of use by the groups

moment: finger, pen, pencil, paper, handkerchief, wooden bangle, etc. (Figure 5). As evident from Table 4, Group 5, whose main strategy was handling, probed the three artefacts most often. Students when probing with pen would often insert the nib into the slots of 'A'/ 'B', either to check the material or rotate the wheels. Students tried several actions with the 3 artefacts, such as testing possible orientations, tapping the surface, shaking, rubbing, pressing the sides of the slots of 'A', rolling 'C' on table and rotating 'C' in hand. Groups 2 and 5 manipulated the artefacts more often than others.

Students tested several of their predictions through actions. These included predictions about (i) material; e.g. testing whether the material of 'C' was magnetic by probing the surface with pen nib (ii) structure; e.g. by probing the slot of 'A' to check whether the wheels inside the slots were moving or not (iii) function; e.g., by rubbing wooden bangle on 'C' to see if 'C' could be used for rubbing on wood. Group 2 tested their predictions most often (16) while Group 6 did so least often (1). Groups which were able to identify the three sharpeners, asked for a knife to test their predictions. They were provided with a blunt knife available in the laboratory. While all the four groups could use 'A' or 'B' in the intended way, none, except one student, could use 'C' in the intended way. However, since the material of the sharpening surface of 'C' was rough they did not reject their hypothesis of 'C' as a knife sharpener.

Figure 5. Probing slot of 'A' with handkerchief

Each group had one or more dominant strategy/ies for investigating the artefacts. For example, the dominant strategies utilised by Groups 1 and 4 were cognitive strategies, especially suggesting more ideas to the groups, questioning others, seeking clarifications, defending and rejecting ideas. The dominant strategies adopted by Groups 2 and 5 on the other hand, were mainly handling strategies. These two strategies were balanced in Group 3 and quite low in Group 6.

Contribution of individuals to groups

It was found that students in all the groups contributed in identifying the functions of the artefacts. However the level of participation of students differed among groups. In both the girls' groups (1 and 2) all the girls equally contributed to the identification process through active discussions and handling of artefacts. Among the boys' groups (3, 4 and 5), one student in each of these groups was less interactive and made hardly any contribution to their

groups. Others in the groups contributed both cognitively and by handling. Group 6 of four members was the least interactive group with one dyad working together while the other two worked individually.

Perceiving affordances and deriving functions

In order to make use of an artefact one needs to perceive the possible actions that could be performed on/with it. As mentioned earlier, Gibson (1979/1986) uses the term *affordances* to refer to the close link between the perceived properties of an artefact and the possible actions that could be done with it. None of the students of the six groups were familiar with the three artefacts used in the study. Hence the clues to identifying the intended functions of the three artefacts were the structural properties that afforded particular actions. For example, 'A' was highly graspable with a handle while 'B' and 'C' were not (Figure 1). Both 'A' and 'B' had slots through which something thin could be drawn. 'C' was rotate-able whereas 'A' and 'B' were not. Artefact that affords more actions would be put to use in more ways than another that affords fewer actions.

In the present study it was found that of the three artefacts, most students across all groups came up with fewer accidental functions for 'B' (4) than for either 'A' (14) or 'C' (16) (Table 5), suggesting that 'B' offered fewer perceived affordances and hence fewer possible uses than 'A' or 'C'. Although students across all groups seemed to appreciate the functional significance of the slots of 'A' and 'B', they found the situation challenging since the slots were narrow and the materials of the wheels in the slots could not be identified easily. For example, even after identifying the similarity in the orientation of wheels in 'A' and 'B', and identifying 'A' as a knife sharpener, Group 4 mistook the material of the wheels in 'B' to be plastic and rejected it as a knife sharpener. Also, the presence of two slots in 'B' made the situation more difficult for them. The presence of a single slot in 'A' perhaps, made it easier for students to

Group 1 (Girls' Group) *Intended functions of A, B, C:* Identified *Accidental Functions:* B - Pencil sharpener (R) C - toy (R) - paper weight (R)	Group 2 (Girls' Group) *Intended functions of A, B, C:* Identified *Accidental Functions:* A - for binding papers (R) - smoothening paper (R) C - to clean surfaces (R) - smoothen wood (R) - smoothen metal (R) - file nails (R)	Group 3 (Boy's Group) *Intended functions of A, B, C:* Identified *Accidental Functions:* A - for cutting papers (R) - putting stamps on paper (R) - paper holder (R)
Group 4 (Boy's Group) *Intended functions of A:* Identified; *B & C:* Not Identified *Accidental Functions:* B - for storing blades (R) C - for wrapping thread around (R) - for wrapping paper around (R) - for wrapping cello tape around (R) - wrapping cloth around as bandages (AD) - as a paper weight (R)	Group 5 (Boy's Group) *Intended functions of A, B, C:* Not Identified *Accidental Functions:* A - act as a lever (ANO) - to straighten something (ANO) B - cover for a torch (ANO) C - as wheels of a car (R) - paper weight (R) - yo-yo toy (ANO)	Group 6 (Boy's Group) *Intended functions of A, B, C:* Not Identified *Accidental Functions:* A - act as a lever (ANO) - gear (ANO) - handle of door (ANO) - part of lathe machine (ANO) - part of compound microscope (R) - for cutting papers (ANO) - for making circles on paper (ANO) B - for storing something (ANO) C - as wheels of remote-controlled car (ANO) - a two wheeled toy car (ANO)

Table 5. Accidental functions identified for each of the knife sharpeners by the groups (Key: R = Rejected after discussion; AD = Accepted after discussion; ANO = Accepted with no objection)

RESEARCH

hypothesise and raise discussions regarding the material and structure of the single slot.

Conclusion

The present study revealed that middle-school students utilised a variety of strategies to identify the intended functions of artefacts unfamiliar to them. Students working in groups used cognitive strategies such as suggesting, critiquing, rejecting, acknowledging and defending ideas, and handling strategies that involved observing and manipulating artefacts and checking suggestions or predictions.

The analysis revealed that each group used one or more dominant strategies to accomplish the task. Brainstorming plays a significant role in creative problem solving (Robson 2002). In the present study all groups had similar capabilities in suggesting new ideas. The differences lay in the use of other cognitive strategies such as criticising, rejecting, seeking or providing justifications for ideas. Accepting ideas without objections was more often found in groups which were unable to decipher the intended functions of artefacts. Unsuccessful groups either did not focus on similarities among the artefacts or found superficial similarities.

Accidental functions for the artefacts were suggested by all groups. However, successful groups later rejected these accidental functions. The accidental functions listed by students were typically related to their daily activities: *toy, pencil sharpener, paper weight, wrapping for cello tape or bandages, handle of a door etc.* If an artefact is to be used, it must fit into the pattern of activity that belongs to a particular lifestyle and set of values (Pacey 1983). Some students found it difficult to come up with the intended functions of the artefacts possibly because knife sharpeners are not very common in Indian homes.

Besides cognitive strategies all groups used handling strategies; they often probed the artefacts with whatever was available with them at the time, such as finger, pen, pencil, handkerchief and paper. Gestures such as pointing were important aspects of interactions whereby students directed attention of other members in the group and ensured their contribution to the identification process. Testing of predictions through actions was found to be particularly useful for students in the identification task.

Though all students contributed to identifying the functions of the artefacts, their level of participation differed. All members of girls' groups contributed equally to active discussions and handling of artefacts, while in the boys' groups one or more student/s did not interact with other members. According to Maltz and Borker (1983), girls use conversation for social binding, while the use of speech to express social dominance is a behavioural pattern commonly found in all-boys' groups.

The analysis suggests that interaction played an important role in identification of the intended function of the artefacts. Groups which were less interactive (also less critical of others' ideas, accepted ideas without objections and were less defensive of their own ideas) were unsuccessful in identifying the intended functions of the artefacts.

Which strategies resulted in groups successfully identifying the intended functions of the artefacts? Both cognitive and handling strategies were important when exploring unfamiliar artefacts. However the duration of handling the artefacts was not indicative of students' success. Various reasons underlie the above. Firstly, one may casually handle the object without focussing on its features. Secondly, unsuccessful groups would continue to handle the artefacts longer than the successful ones.

What about the differences in the artefacts themselves? All the knife sharpeners were unfamiliar but students suggested fewer accidental functions for knife sharpener 'B'. Artefacts that offer more perceived affordances and hence more actions would be used in more and in different ways than others that offer fewer. Thus the number of accidental functions suggested may be indicative of the perceived affordances and perhaps the difficulty in identifying the functions of the artefacts.

Way forward

There are several questions that came up in the study that need to be probed further. Would the strategies change if this activity was carried out with individuals rather than in groups? Secondly, this activity was context-bound, since it was conducted with three knife sharpeners. Would the strategies employed by students change if the artefacts were different from the ones used? How does the nature of design ideas of students change after they have engaged in this activity? These questions are expected to be addressed in future studies that would be undertaken by the authors.

References

Ara, F., Chunawala, S. & Natarajan, C. (2009) 'From analysing to designing artefacts: Studying middle school students' ideas about design and designers'. In Subramaniam, K., & Mazumdar, A. (Eds.), Proceedings of epiSTEME-3: International Conference to Review Research in Science Technology and Mathematics Education, New Delhi, India: Macmillan.

Casler, K., and Kelemen, D. (2005) 'Young children's rapid learning about artefacts'. *Developmental Science*, 8, 472–480.

Crismond, D. (2001) 'Learning and Using Science Ideas when Doing Investigate-and-Redesign Tasks: A study of naïve, novice and expert designers doing constrained and scaffolded work'. *Journal of Research in Science Teaching*, 38 (7), 791-820.

Defeyter, M.A., and German, T.P. (2003) 'Acquiring an understanding of design: Evidence from children's insight problem solving'. *Cognition*, 89, 133–155.

De vries, M. J. (2006) 'Technological Knowledge and Artefacts: An Analytical View'. In Dakers, J. (ed), *Defining Technological Literacy: Towards an Epistemological Framework*, England: Palgrave Macmillan.

Ferré, F. (1995) *Philosophy of Technology*. Athens, GA: The University of Georgia Press.

German, T.P. and Johnson, S.A. (2002) 'Function and the origins of the design stance'. *Journal of Cognition and Development*, 3, 279–300.

Gibson, J.J. (1979/1986) *The Ecological Approach to Visual Perception*. Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Gokhale, A. A. (1995) 'Collaborative learning enhances critical thinking'. *Journal of Technology Education*, 7 (1), 22-30.

Heiser, J., Tversky, B. and Silverman, M. (2004) 'Sketches for and from collaboration'. In J. S. Gero, B. Tversky, and T. Knight (eds.), *Visual and Spatial Reasoning in Design III*, 69-78, Key Centre for Design Research, Sydney.

Kelemen, D. (1999) 'The scope of teleological thinking in preschool children'. *Cognition*, 70, 241–272.

Kroes, P. (2002) 'Design methodology and the nature of technical artefacts'. *Design Studies*, 23, 287-302.

Kroes, P. and Meijers, A. (2006) 'The dual nature of technical artefacts'. *Studies in History and Philosophy of Science* 37, 1-4

Maltz, D. N. and Borker, R. A. (1983) 'A Cultural Approach to male-female miscommunication'. In J.J. Gumperz (Ed.), *Language and Social Identity*, Cambridge, UK: Cambridge University Press.

Matan, A., and Carey, S. (2001) 'Developmental changes within the core of artefact concepts'. *Cognition*, 78, 1–26.

Mehrotra, S., Khunyakari, R., Chunawala, S. and Natarajan, C. (2009) 'Collaborative learning in technology education: D&T unit on puppetry in different Indian socio-cultural contexts'. *International Journal of Technology and Design Education,* 19 (1), 1-14.

Mitcham, C. (1994) *Thinking Through Technology: The Path Between Engineering and Philosophy*, Chicago: University of Chicago Press.

Pacey, A. (1983) The Culture of Technology, Cambridge: MIT Press.

Robson, M. (2002) *Problem Solving in Groups*, Hampshire, England: Gower Publishing Limited.

Vermaas, P. E. and Houkes, W. (2006) 'Use plans and artefact functions: An intentionalist approach to artefacts *and their use'. In Costall, A. and Dreier, O. (eds.), Doing Things with Things: The Design and Use of Everyday Objects*, England: Ashgate Publishing Company.

farhat@hbcse.tifr.res.in
chitran@hbcse.tifr.res.in
sugrac@hbcse.tifr.res.in

RESEARCH