MIDDLE SCHOOL STUDENTS' DEPICTIONS OF STATIC AND DYNAMIC OBJECTS AND ASSEMBLIES BASED ON VERBAL DESCRIPTIONS AND CUES

Gandhimathy S., Ritesh Khunyakari and Chitra Natarajan

Homi Bhabha Centre for Science Education, TIFR, Mumbai, India

School education emphasizes text and reading drawings over making drawings. The present study explored the nature of depictions of objects by middle school students based on given descriptions. The study included four tasks; the first three were contextual descriptions of mechanical objects. In the fourth task students had to associate the descriptions used in the first task with one of the ten given drawings. As was to be expected, students found it easier to depict simple and static objects than complex assembly of objects. Students explored their depictions through rough sketches. They used the given dimensions as labels in the drawing, and rarely used them to depict the proportions of the object in the drawings. Descriptions of assemblies have elicited X-ray diagrams. Common words like, cylinder and pipe triggered depictions of objects associated with these words in everyday life, showing that the images triggered by words played a significant role in their depictions. The study indicates that it is important to engage students at least as much in making drawings as in reading drawings of mechanical objects or systems in school education.

INTRODUCTION

Objects make up the physical world around us. Early humans spontaneously visualized and represented objects through drawings, which communicate to us their understanding of their world of objects. Studies have used drawing and posters made by students to elicit students' ideas about science and technology (Mehrotra et al, 2003). Drawings are the preferred method of external data representation among designers, architects and engineers and it explicitly preserves information about geometry and topology, whereas text is serial in nature (Ullman et al, 1990).

Objects come in varied shapes, regular and irregular, solid and hollow. They may be static or dynamic, and their forms of assembly may be simple or complex. Each object can be said to have an attribute of spatial configuration and of functional aspects. We often understand the diverse objects around us through our knowledge about their spatial and functional distinctions from other objects. Human interactions with the physical world deal with object exploration, maintenance and manipulation.

READING DRAWINGS VERSUS MAKING THEM BASED ON VERBAL CUES

Identification and depiction of objects involves visuo-spatial thinking. Drawings mediate and externalize this visuo-spatial thinking. Some studies have pointed out that expressing ideas in a visuo-spatial medium makes comprehension and inference easier than in the verbal (language) mode (Tversky, 2002).

Reading a drawing involves interpretation of the drawing as a whole. It does not require the reader to pay attention to the details that are conveyed through the graphical elements and spatial features of the object itself. This limits visualization, manipulation and assembly of objects. On the other hand, making drawings involves interpretation of the textual description (meaning making), calling for visualization of the object in space and its representation for a larger audience. According to Baddeley (1993), verbal and spatial components are distinctly processed in the Visuo-Spatial Memory (VSM) buffer. Reading verbal description involves comprehending, visualizing and retrieving, requiring not only vocabulary and grammar but also skills of visualization. Besides, depiction of assembled and dynamic objects entails the visualization of relative position of parts (one object passing through the other) as well as mental transformations.

Drawings and mechanical reasoning

A mechanical system is a combination of static and dynamic objects. Reasoning about assembly and motion of objects constitutes mechanical reasoning. Drawing such objects based on verbal descriptions and cues involves the translation of verbal understanding to spatial depiction, in which both spatial and verbal abilities play important roles. Here the represented world is essentially spatial because assembly and motion are spatial properties. Mechanical reasoning involves the visualisation of the location of objects, their shapes and spatial connectivity (Hegarty, 2004).

Objectives

The present study is an attempt to explore students' representations of simple, complex and dynamic objects and object assemblies based on verbal description or cues relating to these objects. One aspect of the study also focuses on students' preference of an object depiction. The following questions were sought to be investigated: Given a description, including shape and dimensions, of an object, what do students represent in their drawings? Do students have preferred ways of representing objects? Are any of the features described less important than others?

METHODOLOGY

Middle school students were administered four different tasks of varying complexity one after another. They were required to read the given short descriptions in each task carefully and respond to them by drawing the objects on sheets of plain paper. The students took approximately 1.5 hours to complete the four tasks. The pen-on-paper productions were analysed.

Sample

The sample for the study came from the school located in the vicinity of the researchers' institution. It consisted of 60 students from Class 8 (average 13 to14 years), with 21 girls and 39 boys. The students had different home languages, while the medium of instruction at school was English. Students' willingness to participate in the study, their proximity to researchers' institution and the researchers' rapport with the school management influenced the selection of the school.

Four Tasks

The tasks in the study were posed in the form of contextual mechanical problems, that is, textual descriptions of objects posed in a context which required students to make a drawing. Students had to translate the given verbal information to a drawing.

Task 1: In the first task, students had to draw two simple, static, geometric objects (items 1 and 2) and their assembly (item 3). A context was provided to motivate the translation from description to drawings: the drawings were meant for a person who could not read well (a car mechanic who had only studied till Class 3).

Task 2: The second task involved a contextual description (a birthday gift) of three static objects (items 1 to 3), their manipulation and assembly (item 4). Students had to depict the objects and assembly. After they had drawn, they also had to guess to what use the object could be put to.

Task 3: The third context consisted of a cue for students' drawings, where they had to visualize and depict the working and assembly of the familiar mechanical object (a bicycle chain that had fallen off from the gear). Thus it involved a dynamic assembly.

Task 4: The fourth task had the same descriptions as in the first task. This time, these were accompanied by a set of 10 numbered drawings. Students had to choose the drawing they thought were best representations for each description. The set included three depictions for the first (a solid cylinder) and second (a hollow PVC pipe) objects described, and four depictions for the third one (assembly of solid cylinder inside a PVC pipe). The depictions included conventional and diagrammatic perspective representations. The design of this task draws inspiration from an experiment done with nursery to grade 6 (age 4 to 11 years) students exploring the relation of children's drawings and internal representations (Kosslyn, 1977). The task has been modified in the nature of object, perspectives shown and the intervention method for the older children in our sample.

Students could use as many sheets of paper as needed for making exploratory and final sketches. Responses to each task were collected from the students before administering the next task. Researchers took notes about the questions asked by students and the general observations as students engaged with the tasks.

Analysis framework

The pen and paper productions for the first two tasks have been preliminarily analysed based on the following criteria:

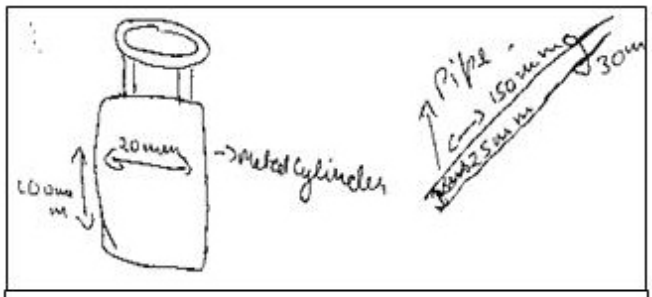
- The nature of the depicted object focused on whether the drawing was that of a geometrical shape as described or an associated familiar artefact.
- The analysis of dimension and proportion looked at the use of the given dimensions in the drawings as labels, through leaders and arrows, etc. It also noted the correct relative proportions of the object (its length versus breadth or diameter, etc.) in the drawings.
- The drawings were analysed in terms of their orientation as being vertical, horizontal or at any other angle with respect to all the objects depicted on a page.
- The preliminary analysis of students' responses in the third task – working of a bicycle chain – was based on the depiction of the two gears in size, structure and proportion, the location of the chain, the pedal attachment and depiction of motion.
- The perspectives – whether diagrammatic, realistic, conventional (technical), mixed, X-ray drawings, etc. were also qualitatively analysed for the first three tasks. For the fourth task

the choice of drawings for each description was noted for each student and the data was analysed for frequency of occurrence of each of the 10 drawings.

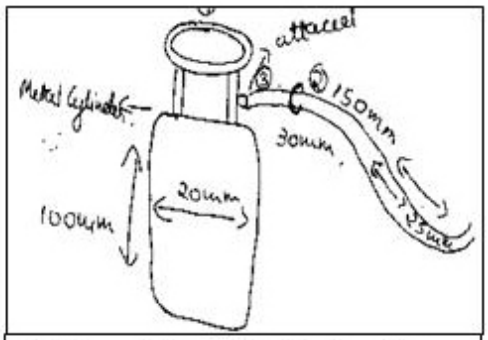
RESULTS AND DISCUSSION

In general all the students drew exploratory sketches before they finalize their productions. All the students depicted X-ray diagrams to show the occluded object. Students depicted, through labelling or using leaders, end-lines and arrows, the dimensions of the objects drawn. However, they were oblivious to the relevance of dimensions in the task.

Task 1: Several students drew realistic pictures of a "gas cylinder" or a "measuring cylinder" in an item in the first task that required them to draw "a solid cylinder 100 mm long and 20 mm in diameter."



1: One 100 mm long solid metal cylinder of diameter 20 mm.
2: One 150 mm long hollow PVC pipe of inner diameter 25 mm and outer diameter 30 mm.



3: The solid metal cylinder (1) has been placed inside the hollow PVC pipe (2).

Figure 1: Drawing of a student for Task 1, showing association of descriptions with a cooking gas (LPG) cylinder.

Terms like "cylinder" and "pipe" seems to have triggered spontaneous associations and visualization of everyday objects and situations, which the students chose to depict these rather than the geometric objects described. Figure 1 shows an example of such a depiction.

A little over half the students were able to depict the metal solid cylinder as a geometrical object. Among these only a few (4) were able to make distinct drawing of the solid cylinder and hollow pipe. Almost half showed associated objects of everyday use.

A detailed description including dimensions of objects triggered the depiction of proportionality of length and diameter in the drawings only among a fourth of the students. In tasks involving drawing straight line objects in perspective, children up to the age of nine have been reported to use vertical oblique projections (Anning, 1997). Similarly in this study almost three fourths of the students depicted vertically oriented objects.

Task 2: The second task which involved a complex assembly was a very difficult one for the students and most made errors in the assembly. The difficulties arose both from the compound shapes and assembly as well as from words like "threading" with which several students were unfamiliar. However, the few who did get the shapes and assembly correct made errors of overall dimensions.

Task 3: Students had to depict the assembly and working of a bicycle chain. In the context provided the bicycle chain had fallen off the gears, which often happens while riding one of the more commonly available bicycles. These have exposed gear and chain assemblies. In order to show how to put the chain back and get the bicycle functioning again, students would have had to draw an assembly of the chain, gears and pedals. Two thirds of the students did see this need and depicted the chain assembly and pedal arrangement. There were interesting gender differences in the depiction of chain assembly: only a third of the girls drew the assembly, while almost all boys did. About a third chose to draw the entire bicycle. A third of the students depicted only one or two parts – just chain or gear, several of which were accompanied by annotations (verbal).

Task 4: Of the four tasks, students found the last one on choosing the drawings for given descriptions easiest to do. Over half the students chose the incorrect options (A, C or G) indicating hollow cylinders when the item described was a "100 mm long solid metal cylinder" (see Figure 2). The correct options (D, E or F) were chosen by less than a third of the students. However, over half the students chose the correct option for the description of a "hollow PVC pipe." Most students were able to choose the correct option for the assembly of the solid cylinder inside the hollow pipe. Three diagrammatic representations (B, E and H) were included among the set of 10 options. However, very few students selected these. This is similar to the results in an experiment by Kossyln et al (1977) among 4-11 year olds, where the children preferred the conventional perspective drawings over the diagrammatic pictures.

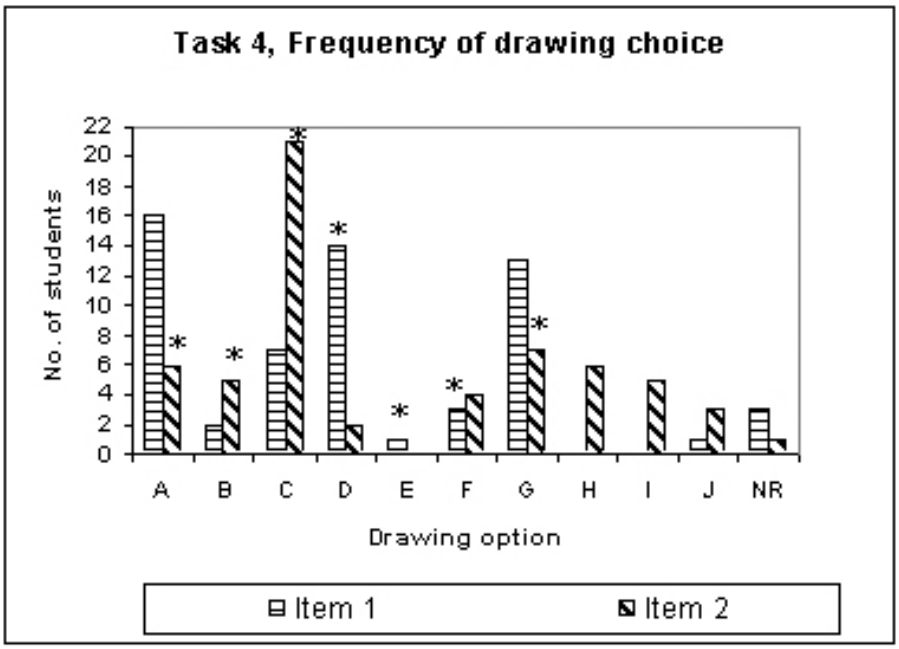


Figure 2: Frequency of drawing choice of item 1 and item 2 in Task 4. Asterisks indicate the appropriate drawing choices for each item.

CONCLUSIONS AND IMPLICATIONS

For children, drawings are a spontaneous form of expression (Ramadas, 1990). It aids in the development of reasoning and problem solving skills, and hence it cuts across all disciplines. Diagrams are given in several school textbooks: science, geometry and geography have many

diagrams. In Indian school curricula, identification and depiction of objects is included in the pre-school and primary levels. At the middle and secondary school levels, emphasis shifts towards the reading of pictures and diagrams and their verbal description. Hence depicting or drawing tasks are either undervalued or isolated into art and craft, also an underrated subject. Drawing and depiction again gains importance at the level of tertiary and professional education, such as science, medical and engineering streams. Unfortunately, undervaluing drawing during the crucial period of children's cognitive development has implications for their long term education. Besides, sketches play a major role in design and technology, which is not a school subject in India (Khunyakari et al, *in press*).

Drawings have been used in this study as a tool to probe students' representation of objects and their assembly and motion. It was found that students could successfully translate verbal descriptions to drawings, when their vocabulary permitted. On the other hand, verbal descriptions also seemed to trigger depictions of associated objects. Most students failed to see the relevance of dimensions, except in a gross way. They did not use the given dimensions to estimate the object's size and shape, skills that are essential for design and engineering. The study suggests that it is insufficient for school curricula to emphasise reading of mechanical drawings, while making drawings is part of art and craft. It is important for the making of mechanical drawings to be integrated into existing school curricula at all stages. Such attempts have been made in the Homi Bhabha Curriculum of the Centre. (Ramadas & Vijyapurkar, 2001)

References:

Anning, A. (1997). Drawing Out Ideas: Graphicacy and Young Children. *International Journal and Design Education,* 7, pp 219-239.

Baddeley, A. (1993). *Your memory: a user's guide*. Penguin Books, England.

Hegarty, M. (2004). Mechanical reasoning by mental simulation. *Trends in cognitive science*, Vol. 8 No.6, pp 280 – 285.

Khunyakari, R., Mehrotra., S. Chunawala, S. and Natarajan, C. (in press). Design and Technology Productions among Middle School Students: An Indian Experience, *International Journal of Technology and Design Education*.

Kossyln, M. S., Heldmeyer H. K, and Locklear, P. E. (1977). Children's Drawings as Data about Internal Representations. *Journal of Experimental Child Psychology*, 23, 191-211, 1977.

Mehrotra, S., Khunyakari, R., Chunawala, S. and Natarajan, C. (2003). *Using Posters to Understand Students' Ideas about Science and Technology*. Technical Report No. 1(02-03), Homi Bhabha Centre for Science Education, Tata Institute of Fundamental Research, Mumbai, India.

Ramadas, J. (1990). Motion in Children's Drawings. In Idit Harel (ed.). *Constructionist Learning*, The MIT Media Laboratory, Massachusetts, pp 249-280.

Ramadas, J. and Jyostana Vijapurkar (2001). The Homi Bhabha Curriculum for Primary Science. In *Abstracts: Science, Technology & Mathematics Education for Human Development, an International Conference on Science, Technology and Mathematics Education (ICSTME 2001)*, Goa, India, p 71.

Tversky, B. (2002). What do sketches say about thinking? Sketch Understanding, Papers from the *2002 AAAI Spring Symposium* 148–151.

Ullman, D. G., Wood, S. and Craig, D. (1990). The Importance of Drawings in the Mechanical Design Process. *Computer and Graphics*, Vol.14, No. 2, pp 263 – 274.