# USING DIAGRAMS IN INCLUSIVE LEARNING SITUATIONS

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*Diagrams and drawings are important tools for understanding science. However, these are often not given due importance in textbooks and specifically braille textbooks. Haptic perception through raised lined diagrams and use of colours give students with/without vision a better opportunity for visualization. Studies have also indicated that interactive peer support strategies help in the successful inclusion of students with disabilities in general education. The study focused on understanding questions raised by students while observing diagrams and how students with visual impairments represent their visualization. It used adapted diagrams with small groups of students to facilitate peer to peer interaction.*

*Keywords: inclusive education, diagrams, collaborative learning, disabilities, students' questions, science education*

## INTRODUCTION

With the current emphasis on educational inclusion, there is a dire need to develop and study effective pedagogies for inclusive science education (Sharma & Chunawala, 2013). Inclusive education along with its many other characteristics "*recognises and responds to the diversity of children's needs and abilities, including differences in their ways and paces of learning. It encourages the use of adapted curricula and teaching devices*" (Jonsson, 1994, p. 158).

In Indian middle school science scenario, learning opportunities that allow students to observe and handle specimens and models, are scarce. Thus, information about structures and functions of abstract entities are accessible to students only through diagrams. Diagrams are important tools for science learners to get access to complex information as these initiate visualization (Uttal & Doherty, 2008). Visual representations through diagrams have a motivating and cognitive role in science communication (Jones & Broadwell, 2008). Besides, development of science and technology depends on visuals *"such as diagrams, illustrations, maps, plots, and schematics."* (Mathewson, 2005, p. 530).

Moreover, drawing of diagrams by students is as important as learning through diagrams. It not only provides a medium to represent the visualization, but also helps them in *"manipulating complex concepts, expressing feelings, observations and perceptions"* (Hope, 2008, p. 170). According to some science educators, a pedagogy centered around diagrams does not require any special equipment to be integrated into normal classroom (Padalkar & Ramadas, 2011). However, a study on Indian textbooks (Vinisha & Ramadas, 2013) suggests that visuals are often not given due attention by textbook writers and publishers.

For students with visual impairments (SVI), the situation is even more problematic as they do not have access to visuals in textbooks. Most brailled textbooks do not have raised illustrations and have "*nothing but pages and pages of boring Braille dots"* (UNICEF, 2000). It is important to note that visualization is not only about vision; the processes of visualization are not disrupted due to vision impairment (Figueiras & Arcavi, 2012). Studies suggest that there is little difference in the perception of spatial relationships by SVI and other students. This may be because the semantic representations used by SVI and sighted students facilitate imagery (Zimler & Keenan, 1983) and knowledge construction by SVI is also supported by haptic perception and verbalization (Figueiras & Arcavi, 2012).

Hill (1995) has reported the use of raised line diagrams for SVI to give them nearly full access to diagrammatic aspects of science. Using multi-sensory approaches in education, such as, the combined use of haptic perception through raised lines, visual perception using colours and verbal descriptions can benefit all students (with vision, low vision or without vision). These help in developing a student centered classroom (Stoffers, 2011) and can enable learners with sensory disabilities to learn with the same resources as used by others (Jubran, 2012).

Heterogeneity exists in the classroom in many forms. Apart from differences of skills, interests and abilities, students also differ in the senses they use primarily for learning. Therefore, when planning pedagogic strategies or learning aids, the teacher must thoughtfully acknowledge such differences (Sapon-Shevin, 2005). One such pedagogic strategy is peer-to-peer interactions in groups (Mehrotra, 2008) which involves collaborative learning and caters to heterogeneous classrooms. Roschelle and Teasely (1995) define collaborative learning as a *"coordinated and synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of the problem"* (p. 70).

## The Study

This study tries to understand the processes involved in the use of adapted diagrams in inclusive collaborative learning situations. Depictive diagrams ("that closely resemble the objects they represent", Mathai, 2013, p. 55) and static models were used to assist visualization and students represented these by drawing diagrams. The study was done in 3 parts; the first 2 parts involved using diagrams, while the third part, used models and verbal descriptions for evoking visualization. The study addresses the following research questions: 1) What do students observe in diagrams in inclusive collaborative learning situations? 2) What questions are raised by students while observing diagrams? 3) How do SVI represent their visualization?

**Sample:** Convenience sampling was used for sample selection for all three parts of the study. **Part 1:** 20 students (Grade 8, age range 13-18) from an inclusive school were selected. Five groups of four students each were formed. Group 1 (3 girls, 1 boy, all had orthopaedic disabilities); Group 2 (4 boys, 2 had orthopaedic disabilities, 1 had no vision, 1 had low vision); Group 3 (2 boys, 2 girls, 1 boy had a learning disability, others had no disabilities); Group 4 (4 girls, 2 had hearing disabilities, 1 had hearing & speech disability, 1 had no disability); Group 5 (4 boys, 2 had orthopaedic disabilities, 2 had no disabilities).

**Tools and administration of Part 1**: Students performed two tasks: A) unguided collaborative observation of 8 large, raised lined, coloured and labelled diagrams of micro-organisms. B) recognizing these diagrams and recalling the names of the micro-organisms the next day. During this recalling of names in task (B), unlabelled, miniaturised, colourless, raised lined, mirror image representations of diagrams in task A were presented to all the students individually.

For task A, an observation sheet was used; groups wrote their observations of the diagrams and questions. Any one member of the group did the writing. Students were allowed to take as much time as they needed to observe and discuss each diagram, and write on the given sheet. Since the session lasted only for 40 minutes, groups observed differing number of diagrams.

(Group 1= 6 diagrams, Group 2= 3 diagrams, Group 3= 4 diagrams, Group 4= 4 diagrams and Group 5= 2 diagrams). We focused on Group 2, which had 2 SVI, to find out if all information was transmitted effectively to them. Some of the responses and questions raised by the group regarding the diagrams of rhizopus and virus are given below.

| | |
|---|---|
|  Rhizopus | **Student observations:** *There are some bacteria like dots in the three circles. (Sporangiospores in sporangia),* *There are some root like bushes at the lowest part. (Rhizoids),* *There is a (horizontal) green bamboo like wood. (Stolon).* **Questions:** *Where are they found? What are the harms and uses due to this? What are the causes of their spreading? What diseases can be caused by them?* |
|  Virus | **Student observations:** *It looks like an alien or robot. Legs are visible in it.* **Questions:** *What disease is caused by it? What is its colour? Where are they found?* |

Table 1: Some of the responses of students in Group 2 to the diagrams of micro-organisms

**Results of part 1:** Collaborative observations of students could be attributed to analogies, such as, "looks like an alien or robot". The questions raised by the students on the basis of these diagrams were non-trivial. The next day, all students including the SVI recognized the diagrams that had been observed by their group from the complete set of 8 diagrams. On the recall task, it was found that the name of Amoeba was recalled correctly by all students (8/8 students of the two groups who had viewed it) while *Aspergillus* and *Chlamydomonas* were recalled by none of the students (0/8 students of the two groups who had observed these).

**Part 2:** 18 students (Grade VII, age range 12-16) from the same school were selected. Students formed 4 groups of their own choice. Group 1 (4 girls, 1 had an orthopaedic disability, others had no disability); Group 2 (5 boys, 2 had hearing disability, 1 had learning disability, 2 had no disability); Group 3 (5 boys, 1 had hearing disability, 1 had learning disability and 3 had no disability); Group 4 (4 girls, 1 had no vision, 1 had orthopaedic disability, 1 had learning disability, 1 had severe skin related illness).

**Tools and administration of part 2:** Students were asked to write the names of different types of teeth and draw their diagrams; this was done to learn their previous knowledge. The SVI was given instructions on a braille sheet, where she could also write and draw. Each group of students were given a set of four different types of diagrams of teeth made by the researcher. Each type of teeth diagram (for example, incisors) was different from another type (canine, molar or pre-molar) in terms of colour, type of raised outline and raised or smooth inner space. Students had previous knowledge about the names and shapes of the four types of teeth through their science textbook, but the SVI had no exposure to the diagrams of teeth as her braille textbook did not have such diagrams.

Students recorded their unguided collaborative observations and questions related to the diagrams, and also drew the four observed diagrams of teeth on the observation sheet individually. The sheets for the SVI were brailled. A video of digestive system was screened in the interval between filling of observation sheet and the test sheet; the latter required students to name and draw all the observed four types of teeth based on recall. Next, students were presented 9 unlabelled raised line test diagrams with coloured outlines, among which four represented the types of teeth shown earlier, while the other five represented different types of cells namely nerve cell, unstriated muscle cells, human cheek cells, onion peel cells and red-blood cells. Students had to recognise the diagrams they had seen earlier.

**Results of part 2:** Only 2/18 students could draw the teeth-diagrams (partially correct) while 9 students could name all the types of teeth correctly. Students' observations of the diagrams often focused on the resemblance of the diagram with some known object. Some responses:

| Student observations | Questions |
|---|---|
| **Incisor:** This shape seems to be like a carrot, -root part of tooth looks somewhat like a hand. | How is its root part (root) formed?<br>Why don't these teeth prick in our mouth?<br>How long is this teeth? |
| **Canine**: This seems to us like an ice-cream. | Why is it shaped so? |
| **Pre-molar**: The crown part looks like teeth itself, but the root looks like a chilli *(mirchi)*.<br>- It looks like radish. | All these teeth look similar. Why is it so?<br>- Why does it look so? |
| **Molar**: This looks like a World cup trophy.<br>- It looks like an Octopus.<br>- This is the biggest diagram among all.<br>- This is helpful in chewing. | Why are they present (in mouth)? |

Table 2: Some responses of students to teeth diagrams

Even when asked to draw while observing the diagrams, an average of 13-14 students drew each diagram correctly. Remaining students (5) either did not draw some diagrams or drew some of them incorrectly. The correctness of a diagram was decided by the presence of the differentiating features of the tooth, such as the outline of the teeth, inner contours, proportion of crown to root, etc. When asked to draw the teeth diagrams from memory after observation, 15 students drew the molar correctly but other teeth (incisors, canines and pre-molars) were drawn correctly on an average by 9-10 students. Reasons why more students drew the molar correctly could be as it was the last observed diagram; or the combination of colour, raised lines and raised inner space are effective aids; or both the above conditions together. Students' performance on recalling the names of teeth was better; the molar was named correctly by 17/18 students while the other three teeth were named correctly on an average by 14-15 students. In the recognition task, all the 18 students including the SVI could recognise the previously observed four diagrams correctly out of the given 9 test diagrams.

**Drawings by the SVI:** The SVI in part 2 stated that she had never drawn anything previously. Her first attempt to draw was by using the stylus and the braille sheet on a braille slate, as seen in (Fig.1 B), where she attempted to draw a canine tooth.

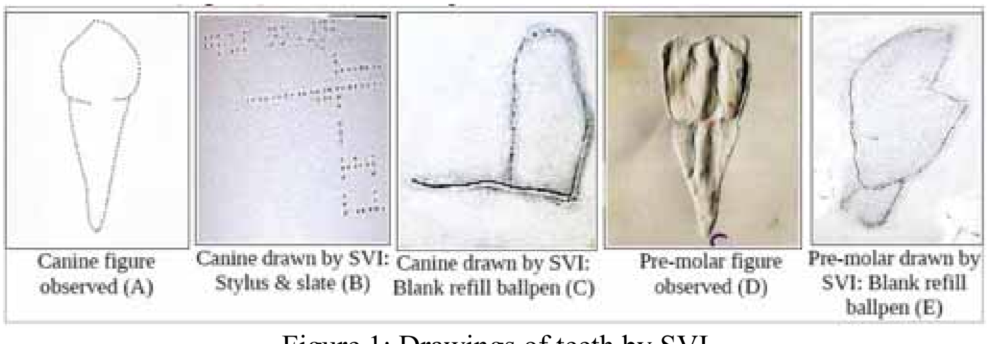


Figure 1: Drawings of teeth by SVI

It is to be noted that she herself was not satisfied with her efforts. Later, she attempted to draw the same on the braille sheet with a blank refill ball-pen. This attempt (Fig 1 C) had the crown part but not the root. Lastly her drawing of a pre-molar (Fig.1 E) with a blank refill ball-pen, on a braille sheet showed both the root and crown. The practice of drawing and the changes in the instrument she used, led to better diagrams. The SVI was helped by her group members in her efforts.

**Part 3:** This was done in a different inclusive setting with 7 students who were studying in different grades (P3 was from primary class; P1, P2, B and F1 were from Grade VIII; R was from Grade IX; F2 was from Grade X). Of these students, 2 (P1 & P2) had normal vision, 2 had no vision (R & F1) while 3 had low vision (B, P3, F2). The student F1 had no vision congenitally. Three days prior to this study, some activities were done with the students related to the basic concept of Atoms (as requested by students). Additionally, students were exposed to some tools that are helpful for SVI in drawing. In part 3, verbal descriptions and models of Rutherford's gold-leaf experiment and resulting atomic model were presented.

Students explored the models and asked questions to understand the experiment and the model for around an hour. The students were then asked to draw the diagram of the setup of the Rutherford's experiment and the model of atom, for which they took around 25 minutes. The model and the descriptions provided a context to ask questions and for discussion. Example of discussions while observing the model of Atom:

F1: ...like I have read in science that the planets revolve... then a question arises do they also collide, so we say that they do not collide as they revolve in their own orbits. Now you say that these (electron in Atoms on basis of Rutherford's experiment) revolve in the same orbit, then would they collide?

Res: This is a very good question... would anyone among you like to tell whether this would happen or not?

B: No they would not collide, they may go behind each other like this (moving finger in circular motion), and their speed would be the same.

R: They would have possibly maintained the distance.

Res: Ok. Is any other way possible?

F1: Sir, I feel that they would collide... because whatever distance they maintain, some misunderstanding is still possible.

Res: Ok. Can anybody else say what other possibilities exist?

F1: Yes... one thing is there, the merry-go-round that goes round-round, in the same manner as it rotates, that too rotates by keeping distance and does not collide. So maybe this is possible. (focusing on motion of the outer edge of merry-go-round)

**Results of part 3:** The SVI in this study along with other students asked some higher order questions related to science and could represent their visualization using diagrams. In Fig. 2, the diagrams of the two models explored and drawn by some students are depicted. The diagrams (B) and (E) were drawn by SVI (R) to represent the models (A) and (D). The student used a bangle to get the ring shape in both the diagrams. She has drawn the thread in diagram (E) which is not part of the atomic model but is part of the teaching aid. Her diagram (B) on the other hand had the essential features of the model except the gold foil which she drew outside the ring. Her drawing had some resemblance to the diagram (G) that was made by student P2 who had normal vision.

The SVI (F1) drew the drawings (C) and (F) to represent (A) and (D), but could draw only some features of the models and missed many details, such as, the 2 slits through which the alpha particle travels. However, he managed to properly orient the source of alpha particles and the gold foil (the alpha particles would hit upon the gold foil). Student R had exposure to drawings previously, but F1 stated that he had no such experience except the exposure he received three days prior to the study.

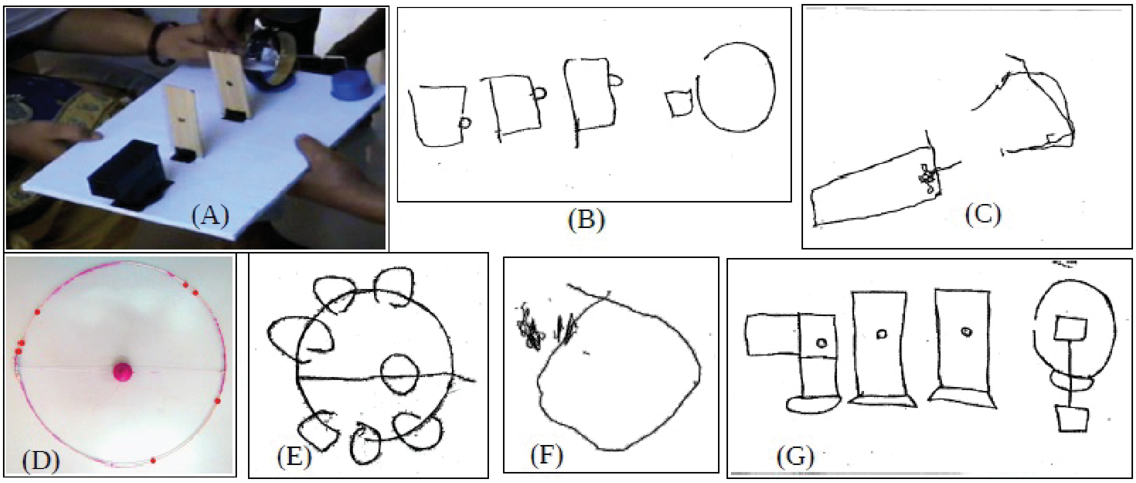


Figure.2: Models observed by students: (A), (D); Diagrams made by SVI-R: (B) and (E); Diagrams made by SVI- F1: (C) and (F); and drawing made by student P2: (G)

## FINDINGS

Collaborative learning settings were found to be effective in the study. In part 1, the two SVI recalled the names of the observed diagrams after a day, despite those names being inaccessible to them in tactile form. They also recognized all the 3 miniaturized, mirror imaged, raised line diagrams from 8 diagrams through touch. A positive aspect of peer interaction and inclusion was seen in part 2 of the study, with peers helping the SVI to draw diagrams. Some findings related to the research questions are:

a) Students' observations in diagrams: Students made analogies of the given representation with common objects, such as, chilli, radish, carrot, world cup trophy, octopus, ice-cream cone (types of teeth), robot (bacteriophage virus), etc. This comparison may have helped students in remembering and recalling the diagrams.

b) Questions raised by students while observing diagrams: The study provided scope for students to raise questions. They spontaneously raised questions, such as; Why is this called so? What does the term mean? Why does it have this shape, colour? etc. Other questions were- does this harm or benefit humans; what are its uses; where are they found? Questions were also aimed at making comparisons between two objects, such as– why do all the teeth look similar? Students also asked questions regarding the materials used in making diagrams.

c) Representations by the SVI: The SVI in part 2 of the study was able to represent the pre-molar tooth by drawings, after using the available tools and with some practice. It is important to note that she had never drawn before. A similar experience was reported by another SVI (F1) in part 3 of the study. In part 3, SVIs also shared their visualizations through verbal descriptions and gestures. The two SVIs (no vision) also made representations with diagrams, one of which had a great deal of similarity with the represented object and also with the drawing made by a student with normal vision.

## IMPLICATIONS

The study reports contexts of collaborative learning through diagrams and models which were successful in evoking higher order questions from students. It suggests that collaborative-inclusive settings are effective for SVIs to draw and learn through diagrams. The study also finds that SVIs manipulate mental images, both visual and/or spatial. Yet, teachers and society in general tend to have low expectations from SVIs (Sacks, Kekelis & Robert, 1992). It is important for teachers to not only recognise the specific learning needs of SVI but also have similar expectations from them, as they would have from their peers (Fraser & Maguvhe, 2008). In the Indian educational context, where SVIs are often not able to select science as a subject for further study due to various constraints, we feel that this ability to manipulate mental images can be tapped by the science curriculum (Sharma & Chunawala, 2013). Diagrams, important in all subjects need to be emphasized in textbooks but more so in the printing of braille textbooks where they are conspicuously absent. Embossed (coloured) diagrams could be effective in inclusive classes for visualization as well as for developing drawing skills in all children. Thus, diagrams can provide students a context to develop higher order thinking skills, to raise questions that are critical and facilitate dialogues with peers.

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