SCIENCE LEARNING AND VISUALIZATION: A CASE OF STUDENTS WITH AND WITHOUT VISION, LEARNING THE ATOMIC STRUCTURE

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Abstract

Knowledge of science and technology (S&T) is a must for optimal social participation of citizens. However, students with visual impairments (SVI) are at a disadvantage while learning S&T due to overemphasis on the visual mode of communication in teaching (Fraser & Maguvhe, 2008). We tried to understand and enhance school learning of SVI through activites using multiple modes of perception and the historical approach to atomic models. The study was conducted with two groups of students in different educational settings; an inclusive setting, and a special educational setting. The study indicates that verbal descriptions; tactile perceptions; 3 dimensional models and objects; and making drawings of perceived concepts were effective in providing learning experiences to SVI and that students in inclusive settings benefited through collaboration. The study highlights the process of visualizing and learning science among SVI and suggests changes in educational methodologies to benefit SVI.

Key words: Science education, students with visual impairments, structure of atoms

Introduction

Visualization involves a series of mental processes which occur in the visual cortex and parietal lobe of brain through inputs from the environment and memory (Trojano, Grossi, Linden, Formisano, Hacker, Zanella, Goebel & Di Salle 2000). According to Vavra, Watrich, Loerke, Phillips, Norris & Macnab (2011) Visualization can be differentiated into -

- Visualization objects: physical objects of representation like, models, pictures, diagrams, geometrical illustrations, animations, videos.
- Introspective visualizations: mental pictures made by the mind (other terms are: mental representation, mental imagery, mental construction, mental scheme).
- Interpretive visualizations: cognitive processes involving the interpretation of both the above, mental manipulation and transformation of objects or representations and transfer from concrete mode to abstract mode of thinking.

The term visual impairment has been defined by the Ministry of Law, Justice and Company Affairs (MLJCA 2005) as any or combination of these conditions: (i) no vision (ii) visual acuity equal or less than 6/60 in the better eye even after using correcting lenses (iii) field of vision equal or less than 20 degree.

Visualization by persons with visual impairments has been a contested topic. Research has indicated that parts of visual cortex in persons with congenital visual impairments get activated when performing activities that involve inputs through tactile form of perception (Sadato, Pascal-Leon, Grafman, Ibanez, Deiber, Dold & Hallet 1996) and during braille reading by persons with no vision (Zangaladze, Epstein, Grafton & Sathian 1999). More recent research has acknowledged that it is possible to have visual imagery in the absence of visual experience (Bertolo 2005). On the contrary there are studies that suggest that vision impairment has an adverse effect on visualization abilities. For example, Cornoldi, Bertuccelli, Rocchi & Sbrana (1993) report that limitations arise for persons with no vision due to higher cognitive load in complex tasks such as matrices of 3-D objects which could be due to the spatial experiences being limited in range. Two studies by Papadopoulos and Koustriava (2011a, 2011b) report an adverse influence of loss of vision on tasks that require visualization for spatial coding and spatial representation. Such studies may have contributed to the general low expectations from students with visual impairments (SVI) which is reflected in the less rigorous mathematics and science curriculum that is offered to SVI at secondary level (XRCVC 2013).

Regarding the science curricula, there are numerous attempts to highlight its importance in the modern world as essential for social participation of citizens (Sharma & Chunawala 2013a). A number of studies have considered science as a special subject that requires a great deal of visualization (Gilbert 2005; Jones & Brodwell 2008; Ramadas 2009) for enhanced learning and understanding. Emphasizing on visualizing experiences in science, the dual coding theory (Clark & Paivio 1991) prefers an 'additive effect of imagery and verbal codes' over 'verbal codes alone' for promotion of better learning experiences. Tversky (2001) promotes the use of visualization objects in science for easy access, integration and operation of information. Vavra et al. (2011) report that imagination of extremely abstract concepts like that of subatomic particles can be successfully offered by scientific visualizations.

However, SVI are often at a disadvantage while learning science and technology because the visual mode, which is unavailable to them is overly used during teaching (Kumar, Ramaswami & Stefanich 2001; Fraser & Maguvhe 2008; Jones, Minogue, Oppewal, Cook & Broadwell 2006). This otherwise useful resource becomes more problematic due to lack of any reference to the considerations of cognition, history and philosophy in teaching (Ramadas 2009, p. 302). Also, such excessive reliance on the visual mode in teaching exists despite the fact that to communicate science, experiences are available through more than one mode (vision) of perception (Figueiras & Arcavi 2012). The process of visualization is a cognitive process and can be aided by explanatory verbal descriptions, tactile and other representations (Heller 2002). To emphasize that persons with visual impairments can pursue and do science, Jones and Broadwell (2008) have highlighted examples of scientists with visual impairments like, William Skawinski (chemist), Larry Hjelmeland (biochemist) and Geerat Vermeij (evolutionary biologist).

In order to reduce the cognitive load of science education for SVI, optional subjects are offered to them. This restricts SVI from pursuing subjects of their interest and their aspirations to get into careers of science are restrained (Sharma & Chunawala 2013b). This situation deprives science from gaining insights and expertise from a diverse group of people with different abilities and forms of perceptions. One such individual Shri. Kartik Sawhney (SVI) had to struggle to opt for science in class XI after being denied by a secondary education board. He later secured 95% marks in science in class XII and is now studying computer science in a reputed university (Chowdhary 2013).

Several studies have focused on modifications that can readily make the experimental as well as theoretical aspects of science education accessible to SVI (Wedler et al. 2013; Kumar et al. 2001). Inclusive education which focuses on considering the learning needs of SVI would be beneficial not only to SVI but also would raise the quality of education for all, regardless of difference in abilities or disabilities (Sharma & Chunawala 2013). There is an urgent need for studies to focus on inclusive curriculum (Jones et al. 2006).

Drawing is one strategy that has been used in this study to provide opportunity to students to represent their conceptual understanding. Drawings in science education tend to be an underutilized resource not only for SVI but also for students with vision. These are often focused merely on the reproduction of bookish diagrams without expectation of any creativity. Glynn (1997) describes students' drawings to be "inherently constructive and motivating for students" (p. 30) when used as a tool to represent the mental models developed after learning. The possibility of integration of a diagram-centred pedagogy is supported by Padalkar and Ramadas (2011).

Another strategy used in this study is collaborative learning which requires peer-to-peer interactions and acknowledging the diversity of abilities, skills and interests of the learners (Sapon-Shevin 2005).

2.Rationale and aim of study

The study was taken up to:

a) find evidences of the three forms of visualization by SVI namely Visualization objects; Introspective visualizations and Interpretive visualizations as described by Vavra et al. (2011).
b) study the learning processes involved in conceptualizing the models of atoms in inclusive and special settings.

The topic of 'structure of atoms' was suggested by two students with no vision from the inclusive settings (F and R) during informal talks. Both students were also a part of the sample of study. This topic is a basic requirement to learn several other concepts of physics and chemistry (Sarikaya 2007), but is a difficult topic as reported by the SVI. Regarding learning the structures of atoms, Harrison and Treagust (2000) suggest that social negotiations among students and use of multiple models of atoms help in a better understanding of the concept. According to them, analogical models are not always interpreted by students in the way they are intended and multiple models are not always easy to understand.

3.Methodology

Science activities related to understanding the structure of atoms were conducted with two different groups of students in inclusive and special (SVI) educational settings. The 'historical approach' to teaching and learning the structure of atoms (Mamlok-Naaman, Ben-Zvi, Hofstein, Menis & Erduran 2005), which was also used in the text-books of the sample students was followed. The sample and settings were selected through convenience sampling.

3.1 Sample: The principals of the schools and students were interviewed to collect data about the sample. These are presented in table I.

Table I: Details of sample

3.2 Settings: a) The inclusive setting comprised of 4-5 students (the number of students differed on different days). The activities with this group were done in a study centre of the National Association for the Blind, in Mumbai where students attend classes. Here all school subjects are taught to SVI and other students who visit the centre regularly. There are also recreational and co-curricular activities conducted for them by special educators and volunteers. All the students are also enrolled in local schools, but reported that they go to schools only for giving their exams. The text-books that the students use are prepared by the Maharashtra State Bureau of Textbook Production and Curriculum Research. These books introduce the concept of Atoms in class VIII (along with atomic models of Dalton, Thomson and Rutherford; concepts of electrons, neutrons and protons, as well as; atomic number, atomic mass number, isotopes and valency). It is important to note that the SVI did not have Braille text-books and were dependent on verbal descriptions by teachers and peers. All the students (F, R, P1, P2 and B) had been exposed to these topics earlier in their normal classroom sessions. Students reported prior experiences of teacher made tactile geometrical figures and maps in other subjects. All except student F in this group had some drawing experiences prior to the study.

b) The special educational setting comprised of 3-5 students (again the number of students differed on different days). Activities were conducted inside the premises of a special residential school for SVI. It is important to note that there was no science teacher recruited in this school. The topics related to atoms were introduced in class IX (as the text-books used were developed by National Council of Educational Research and Training). None of the sample students (S, N, J, K and D) had any exposure to these topics before, despite three of them being in class X. The reason why they had no exposure to these topics according to the students was because there were optional questions in the test paper, that is, SVI were offered other questions instead of these topics. All the students here used braille text-books, but there were no tactile illustrations in these books. Only one student (K) from this setting had some experience of drawing before losing his vision.

3.3 Tools and administration: The categories of visualizations described by Vavra et al. (2011) have been used to understand the visualization done by students during the activities. The activities were performed by the first author on 4 different days and were identical in both the settings. On the first day, students' ideas about atoms were elicited. They were asked to (1) describe atoms (2) give examples of things around them that have atoms (3) and draw how atoms look.

On the next 3 days, the students were given learning opportunities through the following pedagogical framework: (1) Introduction through verbal descriptions and questioning (2) use of 3D representations of the concept to enhance visualization (3) collaboration among peers and author to conceptualize the representation (4) drawings made by learners to represent their understanding of concept. The pedagogy used the historical development of the concept of atoms as theorized by ancient philosophers and scientists, including Dalton, Thomson, Rutherford and Neils Bohr. A historical approach introduces the learner with developments that have undergone with time in the understanding of a particular concept and also about how perceptions of scientists changed regarding the concept. This helps the learners to obtain a basic understanding of the concept and also to cope with misconceptions (Mamlok-Naaman, Ben-Zvi, Hofstein, Menis & Erduran 2005). Students represented their learning through discussions and drawings on the basis of the descriptions, the 3D representations and their previous knowledge. All activity plans and representation used were validated by two science education experts.

3.4 Aids used for representations: To understand Dalton's concept of atom, 8 balls of different sizes were used (6 hard and 2 soft); a water melon (whole fruit later cut to pieces) was used to represent Thomson's concept of atom: a ball surrounded by a beaded ring was used to represent Rutherford's concept of atom; 3 concentric rings with 2, 8 and 2 beads in one plane with a ball in centre was used to represent Bohr's concept of atom and; a 3D representation of the Rutherford's Gold-foil experiment was used.

Table II: Materials used to represent concepts of atoms and experimental setup

The SVIs used tactile drawing board-stylus and touching slate-woolpen (an innovation by Arvind Gupta) and students with vision used paper-pencil to draw. Prior to the study, all the students were given practice with the drawing tools. Students F, S, N, J and D neither had exposure to drawing tools nor got opportunities for drawing prior to this study whereas R, P1, P2, B, and K had earlier exposures to some drawing tools and had prior experiences in drawing.

4.Data and tools for analysis

The data obtained can be categorized as:

(1) Students' understanding about atoms: The views of students were gathered through interviews and comparisons were made between responses of students from inclusive and special settings.

(2) Students' drawings of atoms on the basis of their previous knowledge, and on being exposed to different atomic models: The drawings of students from both settings were compared.

(3) Video transcripts of the activities performed with students: Transcripts and videos were analyzed iteratively to find instances and evidences of visualization done by SVI during discussions. For deciding on whether visualization was being done, the assumptions of dual coding theory (DCT) were used. DCT is a theory of cognition according to which, the verbal and non-verbal (imagery) representations are modality specific and their associative processes explain human behavior and experience. According to DCT, "mental images are also amenable to dynamic spatial transformations that are not possible with verbal representations" (Clark & Paivio 1991, p 152). The theory has been developed in the context of education, hence its use for the analysis becomes more relevant.

With the above theory in view, the responses that represented transformations in mental images were selected and on the basis of the nature of visualized image they were categorized into visualization objects; introspective visualizations and interpretive visualizations. The students conversations in Marathi and Hindi language were also translated for the purpose of reporting.

5. Results

5.1Students' previous knowledge of atoms can be categorized as:

5.1.1 Generalization that all matter is made of units of similar round atoms

Student F (Inclusive setting, perceives only light and dark, no vision) - "Sir I have never seen, but have heard a sentence that the smallest particle of matter is called atom. It is just like a ray (kiran)... which is not visible.. Their shape... seems to me that it would look like a round ray... like it would not be visible to anyone... something must be like telescope by which they might become visible... I feel that it would be just like putting a point. (If we were to view an enlarged image of atom then) it would be like a ball... I feel that all atoms must be similar, of same size, only the things that are small have less and those which are bigger would have larger number of them." When asked about things that have atoms, he replied; "Sir whatever material is made, it must be made up of atoms. Till now I used to think that atoms are present in every matter, I cannot say specifically because it seems to me that atoms are present in everything. Yes like this H_2O, as it is made, it has two atoms of Hydrogen and one atom of Oxygen, water is made up by combination of these, like this...". The student clearly expressed his ideas about the discontinuous nature of matter, made up of discrete units of atoms and could relate the concept to the chemical composition of water. It is obvious that the student had obtained this concept from learning experiences in the classroom. The use of the term ray in the context of atom needs further exploration.

5.1.2 Inability to link the pieces of information to conceptualize atoms

Student R (Inclusive setting, no vision, since the age of 9) - "... atoms are somewhat big-small... whether it is correct or not I do not know. They have classes and remain in them like 2 in this and 4 in that, ... It seems to me that like the atoms in water... like they do not have any shape... like the water does not have any shape, it takes shape of whatsoever we put it... so its atoms are also similar to it. When asked about the shape of atoms in materials other than water; "May be round... I imagine they might be round." The examples he gave about things that have atoms: "Electricity has atoms.. means the one in which light (electricity) is present, they all are made of atoms. Also carrot, skin, glass, water, air, paper have atoms". The latter were asked by the researcher regarding whether atoms are present in them or not. The student's responses point to a lack of clear understanding of the concept of atom. An interesting misconception is evident about the indefinite shape of atoms of water, and the roundness of atoms for other materials.

5.13 Faulty description due to misunderstanding of terminology

Student P1 (Inclusive setting, with vision)- "They are small and irregular, I have seen in my book. When they are spread over bread then they seem black like this (showing the marks in a circle through drawing). They are so many like this. If touched then they get pressed and get attached to our hand. They are in the middle part of bread. They might be like this (showing her drawing). She gave the following examples of things that have atoms:"Atoms must be present in water and on the back of animals. When the bread gets spoiled they are present in that and in chapatis too. I have already seen it on bread, they are of black-white and blue color and they are similar to the thin capsules of cotton." According to her water, skin and air have atoms, but she was unsure about carrot, door and pen. P1's responses could be attributed to a lack of attentiveness or confusion about the terms used in science (in this case 'atom' and 'rhizopus'). It is to be noted that P1 who has normal vision was talking about the Rhizopus or bread-mould that she had learned from her science classes (this is clear from her drawing). P1 reported that the topic of micro-organisms including a description of rhizopus had been covered in their class a few days prior to the study, while the topic on atom was covered earlier.

5.14 Misconception arising from examples provided by teachers

Student P2 (Inclusive setting, with vision)- "Atom is like the material inside a chalk, when we write then it's particles fall down and they have even small particles in them. If we do similar thing with a pencil then the case would be similar to it too. And when our food gets spoiled then they are present even in that. Atoms are round." According to her the following is characteristic of things that have atoms: "They are inside our food when it gets spoiled. They are inside chalk and also in vegetables. When we make dosa-sambhar then what falls from it has atoms. When we make anything from soil even that has atoms. The small particles which fall from the things that we keep rubbing have (atoms)."According to her atoms are present in chalk, vegetables, soil, door and skin, but not in water, air, cloth, glass and rubber. The student considered that atoms are present only in those substances from which small particles fall during rubbing of materials. This misconception seems to have arisen from the examples of atoms being even smaller than the powdered chalks, that generally teachers give while introducing atoms.

5.1.5 Heard about atoms only in context of atom-bombs

Students N, S, J, K (Special setting, no vision and K perceives light and dark) had knowledge about atoms only in the context of atom bombs through their history classes as the topic was exempted from science curriculum for SVI.

5.1.6 Never heard the terms related to atoms before

Student D (Special setting, no vision) reported that he had never heard the term atom before. This is to note that the student was in VI standard while the topic of atoms is introduced to them only after class IX. Also being in residential school the student might have less chance of hearing any related terms from other sources like peers or family members.

5.2Visualization observed during verbal discussions (I refers to the interviewer)

5.2.1Reasoning with Dalton's theory (Interpretive visualization)

F: But sir Dalton's (explanation) seems wrong.

I: Ok, tell me what do you feel is wrong?

F: Sir, like anything that is round we can break it by smashing with some other thing, ok, so theneven smashing it (atoms) with some other thing must break them... or he (Dalton) must tell the reason about why they cannot be broken.

5.2.2 Relating representation with concept (Visualizing object)

F: Look this is Dalton's and this is Thomson's model. Dalton feels that an atom cannot be divided and this is Thomson's model.

B: He looked by opening it and found that electrons were embedded inside the positive charge.

R: Did you eat positive charge or the electron?

B: Did you eat seeds or the pulp?

D: I ate two electrons. (laughs)

5.2.3Knowledge construction through visualization during discussion (Introspective visualization)

Discussion about why some of the alpha particles bounced back after hitting the gold foil, keeping the Thomson's atomic model in mind

F: What could have made it bounce? Did it bounce by hitting the electron or the positive charge?

R: May be they did not get space to pass through the foil, or may be some thing was present there, in the gold foil, which opposed the alpha particles.

F: But if it had opposed then even those would not have passed which actually did.

R: I mean that those could pass through, hmmm, consider that a gold foil is present, then if we hit alpha particles on it then the particles which passed through, they would have been that much strong, I mean this much stronger than gold foil that they would have passed through it. I mean they would have found space to pass in accordance to their size.

I: Ok

R: Is this possible?

I: Yes.

F: But sir, it should be the case... are the sizes of alpha particles smaller and bigger (do they have different sizes)?

I: No all the particles have equal size.

F: Ok why I asked this is because as R has said that those which were smaller would have passed and those are larger in size would not have passed.

I: Can you think anything else?.. Hmmm P what do you think?

B: Sir, they bounced back after hitting, why did not they break away?

F: They might be having this much strength that they would not break. Like sir, we have marbles, so some of them do not break even if hit with a larger force. So I mean that they might not have applied larger force and would have hit slowly.

I: Now we have two possibilities, either the force was less or they were quite strong.

R: If F is saying that they were of same size then whether the foil too... thick from one side and thin from one side... that foil was of equal thickness no?

I: That too had equal thickness.

F: This is the matter sir, whether it stopped after collision with the positive charge or the electron?

I: (Introduction of large empty space in atoms as proposed by Rutherford)

F: Sir sir, but as you have said just now that there remains empty space in it so maximum of these pass through, but if alpha particles had to pass then they would have traveled on the same path, one after the other.. in a straight line only why did they follow a different path.

I: (Explanation of the path of alpha particles)

R: Sir as you said there is a space in between positive charge and electrons then why do not the alpha particles stop in that empty space. (Interpretive visualization)

5.2.4 Use of gesture to visualize the direction (Interpretive visualization)

After the explanation of the momentum of alpha particles and repulsion by the central large positive charge

F: But sir as you have given an example of collision in between two balls, if we throw a ball a larger force then the ball that is this side (gesturing through directing face from one direction to other without using hands) can even push it (the other ball) on the other side instead of repelling back.

I: (Explanation of the centrally placed positively charged mass of the atom which was larger than mass of alpha particles in case of Gold)

F: Ok so it cannot send it away?

5.2.5 Using the visualization of earlier learned model of atom to compare with the new (Introspective visualization)

F: Sir I want to ask that the electrons that are present they only... hmmm... I mean you told that all positive charge is present in the centre, then are there no electrons inside this positive charge? Like if consider watermelon then this is not so inside that, it (positive charge) is present in centre but there even seeds are present. So I wanted to ask that if we look through this point then electrons should also be present in centre (in atom).

5.2.6 Collaborating on how to represent

F: Did you make Dalton's (model of atom)? Make it a little dark.

B: No ... he (Dalton) did not know about what is inside it (atom) .

F: Yes but you need to make it dark (inside of atom as perceived by Dalton).

B: No.

F: Color it smoothly.

B: But when he did not know what is inside it then.

F: But some part of it is visible as white no.

B: White-white is visible only because he did not know about it. At that time he did not know about inside. It was Thomson who came to know about inside.

F: But it is filled from sides.

B: (Tauntingly) filled from sides, this is the shape... this is the shape... (holding F's thumb and explaining by moving her finger along the margins of thumb) you need to draw from the sides but this wont look dark.. you agree no. You need to represent like this.

R: Draw a circle.

F: Ok draw a circle...draw a circle.

(F was telling B to fill the inner space of the representation of Dalton's spherical atomic model, but B was not ready to do so, as this would give impression of something represented inside the atom so insisted on drawing only the margins)

5.2.7 Facing problem to make closed figure (circle):

F: Sir, how would I come to know... then to join it like this... I mean if I want to join it then what shall I do?

Evidences of all the three forms of visualizations being done by SVI were obtained through analysis of their verbal discussions.Such visualizations may be responsible for the higher order thinking among the students during discussions on the Rutherford's experiment. 5.2.3 demonstrates the struggle going on within the minds of students regarding their image of the atom prior to the activities and its mismatch with the activities and the experimental observations. The struggle was identified when it came up in the form of questions in an attempt to fit their observations into the existing mental models.

6. Drawings made by students

Table III: Drawings made by students from inclusive settings

Table IV: Drawings made by students from special settings

In this study the student F who has no vision (congenitally) seems to have a better concept about atoms as compared to his peers. He also had a habit of reasoning about every new piece of information and comparing it with his existing knowledge. The drawings of F indicate his better understandings of atoms and their structure. Student R (with no vision) and students P1 and P2 (with vision) who were from inclusive settings and had prior experience of drawing had a lot of similarities in their representations. A reason for this similarity was the use of bangle by R to draw circles, from whom P1 and P2 also got the idea to do so. Thus interestingly the students with vision got the idea to use an aid from a student without vision.

The drawings of those who did not have any prior experience of drawing are interesting. The drawings of N, S, D, and J (from special settings) were unrepresentative of the visualized object. This may be due to lack of any prior experience and exposure to drawing. On the other hand the drawings made by F (from inclusive setting) had some elements that were representative of the visualized concept or the object. Such a difference may be due to more opportunities of appropriation and collaborative scaffolding among students in inclusive settings (Mäkinen & Mäkinen 2011) which was lacking in special settings, but this needs to be studied further.

The students in the inclusive setting were found to be aware of the difference in the styles of perceptions of their differently abled peers and they used this knowledge to collaborate with them for learning. This seems to be an advantage while collaborating with learners with different perceptual abilities. Such interactions were lacking in the special settings as all the students had similar modes of perception.

As evident from the drawings made by SVI and the verbal comments made by them during drawing, the making of closed figures like circle without a tool is a problematic task for SVI as the linking of starting point with the end point to close the figure is very difficult for them. The discussions of the SVI and collaborative learning observed during the activities in inclusive settings indicate that the pedagogical framework used in this study seemed to be conducive for SVI in such settings.

7.Conclusion

Students in special setting in our study seemed to be at a disadvantage as compared to students in the inclusive setting. They lacked any previous knowledge about atoms, probably due to the lack of opportunities of learning from peers as their school was residential and enrolled only SVI. Another reason was the lack of resources and knowledge that could have been available from a science teacher, and the low expectations from SVI (Sacks, Kekelis & Robert 1992) that lead teachers to skip some topics in science. All or some of these factors ultimately lead to omission of the topic of atoms from their curriculum.

The study also offers evidences of all the three forms of visualization namely visualization object, introspective visualization and interpretive visualizations by SVI. These were done through verbal descriptions, discussions, tactile perceptions, 3 dimensional models and drawings. It is implied that in laboratory conditions SVI may not perform as good as their counterparts with vision (as mentioned earlier about the contradictory studies) but in class room learning situations they can perform well. The reasons may be the non-familiarity of the activities that are selected for experimentation with SVI. The evidences of visual thinking by SVI during reasoning with the mental models of atoms are enough to support the author's views on raising the expectations from SVI in science.

The study highlights the need for an inclusive environment and use of multi-sensory approach for science learning which supports collaborative learning among students (Stoffers 2011) with vision, low vision or without vision. This can also enable learners with sensory disabilities to learn with the same resources as used by others (Jubran 2012).

The study supports the use of students' drawing as a thinking and visualization tool provided that some more appropriate tools be developed that can ease the efforts on the part of the SVI. For example a tool, 'Sewell kit' has been described by XRCVC (2013), but research still needs to be directed at effectiveness of this as a drawing tool for SVI.

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Table I: Details of the sample

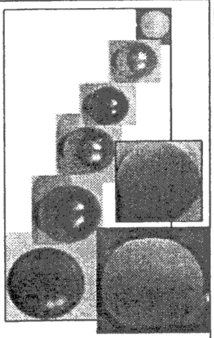
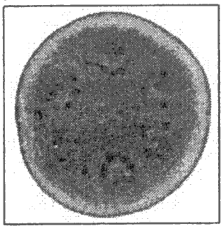
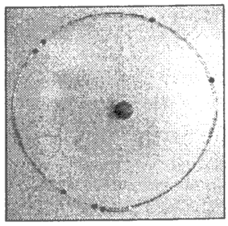
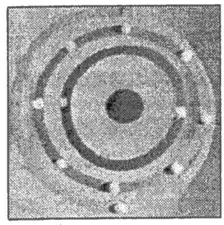
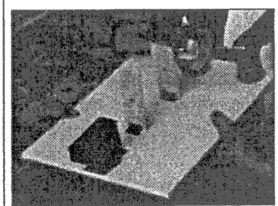
Dalton's concept of atom	**Thomson's concept of atom**	**Rutherford's concept of atom**	**Bohr's concept of atom**	**Gold foil experiment**
				

Table II: Materials used to represent

concepts of atoms and experimental setup

Educational setting	Student	Status of vision	Age	Gender	Class
Inclusive	F	Perception of light and darkness only (congenital)	15	Boy	VIII
	R	No vision (lost after age of 9 years)	15	Girl	IX
	P1	With vision	13	Girl	VIII
	P2	With vision	13	Girl	VIII
	B	Low vision	17	Girl	X
Special	S	No vision (congenital)	15	Boy	X
	N	No vision (lost after age of 4 years)	13	Boy	VIII
	D	No vision (congenital)	14	Boy	VI
	K	Perception of light and darkness only (lost after age of 8 years)	18	Boy	X
	J	No vision (lost after age of 2 years)	18	Boy	X

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Table III: Drawings made by studentsfrom inclusive settings

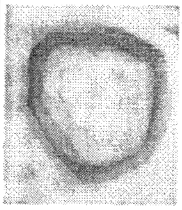
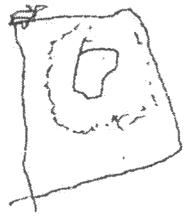
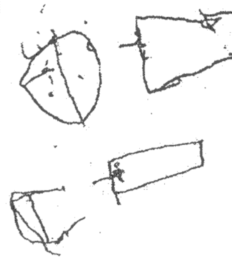
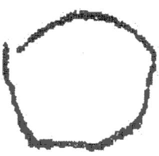
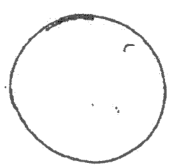
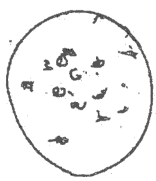
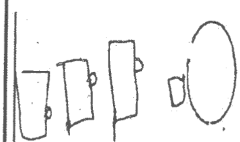
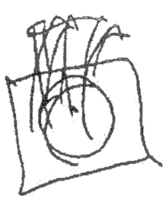
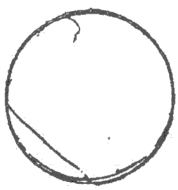
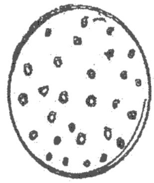
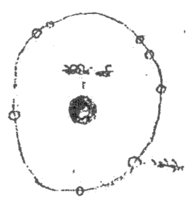
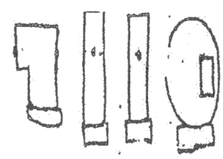
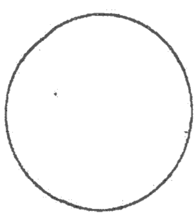
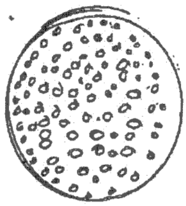
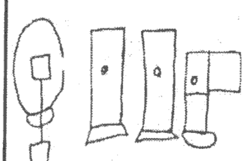
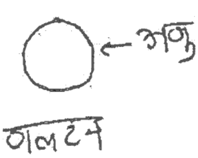
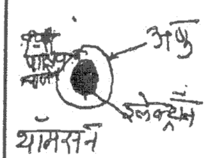
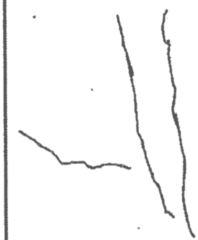
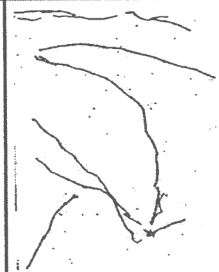
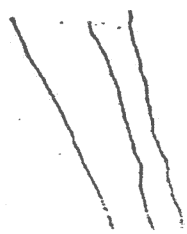
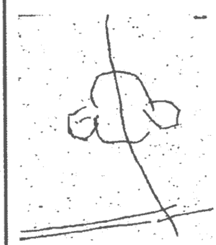
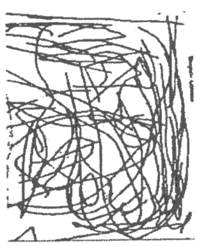
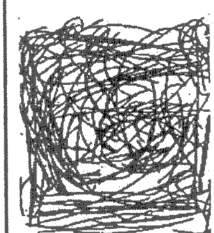
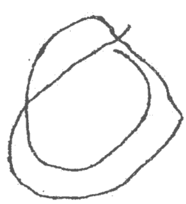
Student	Single atom through previous knowledge	Dalton's atom	Thomson's atom	Rutherford's atom	Rutherford's experiment
F					
R					
P1					
P2				Did not draw	
B	Did not participate			Did not draw	Did not draw

Table IV: Drawings made by students from special settings

Student	Single atom through previous knowledge	Dalton's atom	Thomson's atom	Rutherford's atom	Rutherford's experiment
N					Did not draw
S	 Helped by teacher to draw circle				Did not draw
D	Do not know				Did not draw
J		Did not participate	Did not participate	Did not participate	Did not participate
K		Did not participate	Did not participate	Did not participate	Did not participate