An Analysis of Students' Drawing and Labelling Skills in Science at the Elementary Level

DEBARATI DHAR* AND GOWRAMMA I.P.**

ABSTRACT

Science, with its emphasis on facts and knowledge, is incomplete without skills like observation, interpretation, and analysis. One of the media through which they are expressed is drawing and labelling. There is especially unique need of drawing and labelling skills in biology because of the variety, complexity and intricacy of the diagram and the role it has on developing the concept. The purpose of this paper is to investigate and analyse the strengths and weaknesses of students in drawing and labelling skills and to determine the improvement in these skills after implementing intervention. Class VII students constituted the target population and were selected using purposive sampling. Both exploratory as well as experimental research designs were used. A pre-test post-test single group design was adopted. The data obtained was analysed using both descriptive and inferential statistics. Results indicated that majority of the respondents lacked all the 10 drawing and labelling skills tested. This casts doubt on the students' understanding of biological concepts and hence their overall performance in the subject. After planned intervention, though there was a gain in skills, significant variation in gain percentage was observed indicating individual uniqueness. This suggests the need for using a variety of approaches to develop drawing skills.

Introduction

There are many skills that are required for learning science. The important among them are skills of observation, problem solving, drawing and labelling, analysis, synthesis and creativity. One of the

* *Student of M.Sc in Zoology, Ranchi University, Ranchi, Jharkhand, India.* (e-mail: dr.debarati@rediffmail.com)

** *Associate Professor,* Regional Institute of Education, Bhubaneswar, Odisha, India. (e-mail: gowriip@yahoo.co.in)

Author Note

This article is based on the Dissertation by Debarati Dhar, as an M.Ed student in the Department of Education, Regional Institute of Education, Bhubaneswar in the year 2014–15, under the supervision of Dr. Gowramma I.P.

essential skills of science is drawing and labelling. For improving the interest towards science education among the children, mastery in drawing and labelling skills are important because an excellent way to describe a scientific phenomenon is through drawing. It helps to increase critical thinking, problem solving and creativity among students. Physics, chemistry and biology, all these school science subjects call for drawing skills. There is especially unique need of drawing and labelling skills in biology because of the variety, complexity and intricacy of the diagram. But the role of drawing skills in the teaching and learning of biology has often been underestimated. The goal of the observer is normally to move beyond simple mental images of what observer believes a particular plant or animal looks like, and instead concentrate on the unique identity of that specimen (Dempsey and Betz, 2001). Such approaches to learning in biology will help students relate structure to function to a great extent.

Importance of Drawing and Labelling Skills in Biology

Biologists recognise the usefulness of drawing and a good deal of time is used on it in the lab, in anatomical and microscopic studies, and in the field (BSCS, 1992). Research results have shown that science teachers continue to teach science using the lecture method despite the recommended guided discovery/inquiry methods and the acceptance of these methods by teachers at organised training and orientation courses (Wekesa, 2013a, Landin, 2015). The inability of science teachers to apply these recommended approaches in their teaching is hinged on some teething problems which include lack of laboratories equipped with facilities in schools, large class sizes of science students with very few teachers and competency problems arising from the training of science teachers. This tends to suggest that poor science learning by students is traced to the teachers' fault-in the area of competencies. As a result, many students are intimidated by drawing exercises and resort to copying drawings from lab manuals and textbooks. All the domains of a student, i.e., cognitive, affective, psychomotor are engaged in the learning process when they are involved in scientific drawing. These make students to be creative and learn at a deeper level as compared to surface learning (Rogers, 2008).

Alkaslassy and O'Day (2002) note that observing is a fundamental science process skill. Students observe objects and events using all five senses and learn about the world around. One has to look

at a specimen very carefully to be able to draw it accurately, and labelling of a drawing forces one to think about the component structures and their positions. This means that labelling of drawings in Biology sharpens a student's observation and thinking skills making student able to relate structure to function.

Drawing enhances communication skill especially where students are required to make elaborate descriptions of phenomena which are changing in shape and appearance (Yockey, 2001). A good example could be expressing the process of plasmolysis in plant cells where diagrams can be used to express the physiological changes that are taking place. Drawing is used to transfer information and to solve problems by virtue of its effect on senses. This is so because approximately 80 per cent of our sensory input comes from our visual system. Visual language is very helpful in the learning process, and there is a lot of information that can be transferred in a visual way especially in the sciences. Line drawings, diagrams and photographs can elaborate and make memorable the text that they accompany. The essential concepts are presented in a quickly read format. For example, diagrams can be a powerful tool for summarising the relationships between photosynthesis and respiration. These two related concepts contain numerous difficult-to-learn biochemical cycles and information that students must disentangle, segregate, group and compare. Drawings show student's misconceptions very clearly, teachers can anticipate which concepts are likely to confuse the learners and hence take necessary precautions as they prepare for instruction. Research and classroom experience suggest that students who learn such cycles from diagrams rather than from prose do better. Many studies have also revealed that students seem to perform better in topics that are taught using drawings on final examination. It has a significant effect on performance in Life science (Wekesa, 2013b).

Functions of Drawing and Labelling in Biology

Aggarwal (2001) reported that the making of drawings in Botany and Zoology is an accepted technique. He notes that drawing in biology performs the following functions:

(i) It ensures that the pupil look at and examine the details of the specimen with proper attention. This ensures meaningful learning which will be translated into good performance in biology.

(ii) It provides avenues for learning through visual and kinaesthetic experience in addition to the auditory experience of listening to the teacher. This breaks the monotony during the learning process resulting in increased attention span.

(iii) It provides a record of the work done by the pupil.

(iv) It provides the pupil with material useful for revision. As it will be noted later that drawings can be used to summarise a large content of information. This makes it an excellent tool in preparing for examinations.

(v) It acts as a medium for analysis and synthesis, that is to be a stimulus to think. Analysis and synthesis are among the high domains of Bloom's taxonomy of objectives. This suggests that making of drawings encourages deep learning.

Benefits of Student Generated Diagrams

Janice and Clement (2008), in the research on the beneficial effects of student-generated diagrams versus student-generated summaries on understanding of concepts, have found out that the group which generated diagrams after a brief exposition on a given concept out-performed the one which generated summaries in a test. This may be attributed to the effect of dual-coding of the memory. There is strong evidence that when learners draw diagrams or pictures to represent the facts they have learned makes them stick in their mind better than pages and pages of notes.

Most importantly, it improves the visual perceptual ability in comprehending and understanding the abstract concepts. This is so because approximately 80 per cent of our sensory input comes from our visual system and there is a lot of information that can be transferred in a visual way especially in science (Ostrogona and Mulyandi, 1999). For example, diagrams can be a powerful tool for summarising the relationship between photosynthesis and respiration. These two related concepts contain numerous difficult-to-learn biochemical cycles and information that students must disentangle, segregate, group and compare. Research and classroom experience suggest that students can learn such cycles better from diagrams rather than from prose (Dempsey and Betz, 2001).

From the foregoing, it is evident that making of drawings during biology lessons is aimed at intentionally engaging students meaningfully and in appropriate learning tasks. This participatory learning approach fosters deep learning and high retention rate.

Practical work in biology like in other science subjects is very essential in making concrete the otherwise abstract subject matter.

Rationale of the Study

The age of old chalk and talk method of teaching biology is getting modified and is being supplemented by using digital media, and students are missing out the opportunity to learn through modelling. So, in the digital media the teachers go for less of demonstration of how to draw a scientific diagram. Most of the teachers' use textbooks, charts, models and learners are asked to draw diagrams from them. Though this strategy is very effective, without proper guidance, modelling and monitoring, the crucial point of developing drawing and labelling skills can be missed.

Recent studies (Australian Academy of Science, 2009) show that annotated drawing is a metacognitive strategy and there is an understanding with the efficacy of drawing for meaningful biology teaching and learning. It is shown that when students draw, label and give functions of the labelled parts, they are able to construct meaning to concepts. Some teachers mainly reward high marks to drawings that are very artistic but scientific drawings are not just works of art, but they should meet the criteria of accuracy, clarity, labelling and magnification.

Based on the above discussion, it is observed that mastery in drawing and labelling skills is not just a simple task. The search for ways to bring out effective teaching and learning of biology has provided the impetus for this study. Hence, the need was felt to analyse, identify the strengths and weaknesses and investigate the effect of intervention for improving the drawing and labelling skills in biology.

Materials and Methods

Exploratory as well as experimental methods were adopted. Pre-test and post-test single group design was taken. Around 27 students of Class VII were taken by adopting the purposive sampling method. A pilot test was performed on a student randomly selected from Class VII and a self-developed test was prepared comprising diagrams in biology (chapters were nutrition in plants, nutrition in animals, respiration in organisms and reproduction in plants) based on a Class VII Science textbook of NCERT. Validation of tools has also been done through expert

validation, pilot testing, checking feasibility, scoring pattern and time to be given.

Table 1
Questions and marks distribution on the basis of skills

Sl. No.	Content	Topic	Skills			Total
			Giving title	Drawing	Proper labelling	
1.	Nutrition in plants	Photosynthesis	1	2	2.5	5.5
2.	Nutrition in animals	Human digestive system	1	3	5.5	9.5
3.	Respiration in organisms	Mechanism of breathing	2	3	3	8
4.	Reproduction in plants	Self- pollination and cross-pollination	2	3	2	7
Total			**6**	**11**	**13**	**30**

The drawing test in both pre-experimental phase as well as in post experimental phase was analysed quantitatively by calculating mean, standard deviation and t-test. Qualitative analysis was carried out by percentage analysis to observe the individual improvement with reference to accuracy and reduction in error.

After analysing the student's skills, some practical and activity-based teaching plans for biology of NCERT textbook of Class VII were prepared. During the intervention strategies like engaging learners in practical work for observation, use of audio-visual aids, providing opportunity for clear magnification as it improves visual perceptual ability in understanding abstract concepts (Ostrogona and Mulyandi, 1999) were followed. Misconceptions, confusions and incoherent knowledge on topics were cleared. The specific strategies like use of worksheets, textbooks and teacher demonstration, class discussions, assisting learners at individual level, deliberating instruction on drawing of biological diagrams, giving feedback were applied.

The duration of intervention was one week. It was both classroom as well as practical-based. Some classroom based interventions were given in a group like giving guidance for indicating title per diagram and suggesting proper use of pencil for diagram, showing video of breathing mechanism and pollination to

clarify misconceptions and confusion. Whereas some classroom-based interventions were assisted at the individual level like giving 3D puzzles of digestive system and to rearrange it accordingly, providing worksheets for practicing proper labelling. Practical-based interventions were engaging learners for observation like concentrating on the unique identity of a specimen (Dempsey et al. 2001) and also keeping accurate record of the organism's shape, different parts in proportion to each other while showing and describing model of human digestive system and measuring chest while inhalation and exhalation. A post-test was performed after the intervention where significant improvements were noticed.

Results and Discussion

The pre-test and post-test scores related to the performance of the students were compared to see the significant mean difference in over all scores and the three different categories assessed under drawing and labelling. The details are given in Table 2.

Table 2
Mean, SD and 't' of the skills in pre-test and post-test

Categories of skills assessed	Groups	N	Mean	SD	't'
Total	Pre-test total	27	10.33	4.252	13.989**
	Post-test total	27	21.37	5.168	
Skill of giving title	Pre-test	27	1.85	0.907	16.637**
	Post-test	27	5.33	0.832	
Skill of drawing	Pre-test	27	4.22	1.717	9.084**
	Post-test	27	8.11	2.293	
Skill of labelling	Pre-test	27	4.26	2.490	8.270**
	Post-test	27	7.93	2.745	

**P<.01

The two tailed dependant t-test indicated that there was a statistically significant difference between the pre-test and post-test scores with [t(26)=13.98, p < 0.01] for the overall scores. Similarly, t-values for pre-test and post-test scores under skill of giving title, skill of drawing, and skill of labelling [t(26) = 16.637, p < 0.01], [t(26) = 9.084, p < 0.01] and [t(26) = 8.270, p < 0.01], respectively, were significant at 0.01 level.

Further analysis was carried out to ascertain the individual improvement for all the participants of the study. The same is given in Table 3.

Table 3
Analysis of individual gain in pre-test and post-test

Participants	Pre-Test Score	Post-Test Score	Gain Score	Gain Percentage
1	7	21	14	46.66
2	8	22	14	46.66
3	13	27	14	46.66
4	7	15	8	26.66
5	3	15	12	40
6	7	19	12	40
7	10	21	11	36.66
8	10	27	17	56.66
9	15	26	11	36.66
10	10	23	13	43.33
11	3	20	17	56.66
12	12	22	10	33.33
13	4	5	1	3.33
14	10	23	13	43.33
15	11	18	7	23.33
16	18	26	8	26.66
17	14	26	12	40
18	8	21	13	43.33
19	6	18	12	40
20	17	29	12	40
21	18	29	11	36.66
22	12	23	11	36.66
23	6	23	17	56.66
24	14	21	7	23.33
25	10	24	14	46.66

Table 3 reveals that all students have shown improvement in their performance with a variation in gain percentage ranging from 3.33 per cent to 56.66 per cent. Two students improved very little and the gain in score is 1, indicating gain percentage of 3.33. This confirms that intervention leads to improvement with individual variation. Same strategies may not be useful for improving all students at the same level. Either the duration of the intervention has to be increased with the same strategies or different strategies have to

be tried out for further improvement of those students whose gain percentage is minimum. Further analysis and exploration need to be done for identifying the reasons for persisting difficulty and to ascertain the benefits of prolonged intervention.

The data were further analysed to assess the improvement of students under each criterion measured in the test. All the criteria along with the number and percentage of students performing the same in the pre-test and post-test are given in Table 4.

Table 4
Number and percentages of students achieving mastery under each criterion in pre-test and post-test

Sl. No.	Criterion measured	Performance of Students			
		Pre-test		Post-test	
		Number of students achieving mastery	Percentage of students achieving mastery	Number of students achieving mastery	Percentage of students achieving mastery
1.	Title of the drawing	3	11.1	25	92.6
2.	Drawing magnification	0	0	11	40.7
3.	No overlapping of drawing parts	4	14.8	12	44.4
4.	Drawing correct scale bar	0	0	7	25.9
5.	Drawing done by pencil	22	81.5	26	96.3
6.	Neat and clean drawing	17	63.0	24	88.9
7.	Drawing by using scale	18	66.7	27	100.0
8.	Correct labelling	3	11.1	20	74.1
9.	No crossing of label lines	25	92.6	27	100.0
10.	Arrows in labelling	15	55.6	23	85.2

From the results depicted in Table 4, it can be construed that majority of the respondents lacked all the 10 biological drawing and labelling skills in pre-test. This indicates that they could not record and present their observations during experiments accurately in form of diagrams. This casts doubt on the students' understanding

of biological concepts and hence their overall performance in the subject. The result also corroborates the work of Alkaslassy and O'Day (2002), Ostrogona and Mulyandi (1999), Janice and Clement (2008), and others. However, with reference to each criterion shown, there was overall improvement in post-test compared to the performance in pre-test. The percentage of respondents indicating lack or gain in each skill is discussed hereunder based on Table 4.

Title of Drawings

Nearly 90 per cent of students did not indicate the titles of their drawings in pre-test. The title of a biological drawing should be underlined and must indicate the view of the drawing made (Geoff, 2000). Negligence to indicate titles to drawings could be due to lack of guidance by the teachers or forgetfulness on the part of the learners. But 92.6 per cent of students had given title to their drawings in post-test. The strategy that had worked for learning this skill can be one simple instruction and explanation of the importance of title per diagram.

Magnification

During the pre-test, it was noted that none of the students had the skill of magnification of a diagram. Indication of magnification is important for keeping an accurate record of the organism's shape. In one diagram, it was noted that the shape of stomach was rectangular whereas in some others circular. This type of error could be attributed to lack of attention paid to details or due to lack of conceptual clarity about the process of digestion. After the intervention, around 40 per cent of students learnt how to magnify a diagram. This clearly indicates the complexity associated with the development of this skill. The strategies worked for installing this skill may be engaging learners in practical for observation, instructing students about drawing and labelling skills and use of audio-visual aids for more clear magnification so that students understand the concept. In previous studies, it had been found that drawing and labelling skills improve the visual perceptual ability in understanding the abstract concepts. This is so because approximately 80 per cent of our sensory input comes from our visual system and there is a lot of information that can be transferred in a visual way especially in science (Ostrogona and Mulyandi, 1999).

Drawing with Overlapping of Parts

In pre-test, only 14.8 pre cent of students could draw without overlapping the parts. This lead to misconceptions and resulted in perceiving false information. In one drawing, it was noticed that liver was overlapped by gall bladder and both of them were of equal size. The reason behind lack of this skill can be the distorted image and lack of visual perceptual ability and thus no clear concept. In post-test, 44.4 per cent of students did draw diagrams without overlapping the parts and 55.6 per cent of students have still drawn diagrams with overlapping one part with the other part. The strategies worked behind this may be using 3D puzzles of digestive system, audio-video aids for clear magnification and assistance of learners at individual level. In previous studies it was found that it improves the visual perceptual ability in comprehending and understanding the abstract concepts. This is so because approximately 80 per cent of our sensory input comes from our visual system and there is a lot of information that can be transferred in a visual way especially in science (Ostrogona and Mulyandi, 1999).

Making Drawing with Proper Scale Bar

In a morphological diagram, where the objective is to make a life-like representation, it is very important to keep the different parts in proportion to each other. This is achieved by using construction lines and frames. This results in depicting mastery of making proportional drawings. The study shows that none of the respondents were able to make a proportional drawing and even after intervention many could not develop this skill. In one drawing, it was noted that the size of stomach was larger than liver. This is not the case in the real specimen. The largest organ is liver. In another instance, there was no difference between buccal cavity and salivary gland and were drawn in the same position. The size of the structures in drawings, compared to one another was not a true representation of the real specimen as it should be in morphological drawings. In another instance, there was no difference between the size of chest during inhalation and exhalation. This amounts to be an incorrect record and presentation of what was observed since a biological drawing should be a detailed and accurate representation of a specimen. It should depict the real specimen for future reference. Previous studies (Bolanle and Soladoye, 2014) also reported that students have difficulty, many misconceptions, confusion and incoherent

knowledge on some topics which include many abstract concepts that are difficult to understand, to learn and to remember. Lack of the ability to draw proportional drawings could be attributed to lack of observation skills and misconceptions, lack of practice in making of biological drawings, theoretical approach to teaching and learning of biology, and lack of guidance and feedback.

Though the strategies like class discussion, engaging learners in practical for observation, instructing students about drawing and labelling skills, use of audio-visual aids for more clear magnification were made use of, in the post test only 25.9 per cent of students learnt to draw a diagram with a proper scale bar and 74.1 per cent of students sketched with incorrect scale bar. This indicates the need for prolonged intervention by focussing into the aspects cited above to improve this skill.

Drawing in Pencil

It is highly recommended that all biological drawings must be drawn in pencil to allow corrections to be made. The main outlines should be drawn faintly with 2 HB pencil. When satisfied, a sharp HB or 2B pencil should be used to go over the lines firmly. The study indicated that majority of the respondents (81.5 per cent) had the idea that biological drawings are drawn in pencil. However, 18.5 per cent of the respondents used ball pens. Use of ball pen in making drawings of specimens lowers performance in examinations. This could indicate lack of guidance from teachers and poor provision of learning resources like pencils by parents and guardians. It also indicates lack of knowledge about the correct pencils required to make biological drawings. Use of ball pens makes correction of mistakes in the drawings difficult and often leads to untidy drawings. The probable reason behind using ball pen for drawing diagrams can be highlighting the parts. In post-test, only one student had drawn with pen who did not benefit from the strategies used during intervention, reason for which needs to be explored.

Neat and Clean Drawing

In pre-test, 63 per cent of students sketched neat and clean diagrams and 37 per cent of students drew untidy diagrams. In many drawings, it was noted that there were too many shading and sketchy lines. Dempsey and Betz (2001) had explored the reason for untidiness as —

(i) Use of incorrect materials like non-recommended pencil, eraser and paper.

(ii) Lack of competence in drawing of specimen which leads to unnecessary erasing.

(iii) Lack of attention to detail.

But in post-test, nearly 90 per cent of students prepared neat and clean diagrams and around 10 per cent of students did untidy drawings. The strategy that had worked here could be promoting the use of appropriate materials, encouraging observation and creating pleasure for a neat and clean drawing.

Drawing by Using Scale

Drawings in science, especially in biology, are to be done in free hand. In pre-test, 66.7 per cent of students did free-hand drawing and the others used scale while drawing. The probable reasons could be poor development of eye-hand coordination, or inability for making an artistic drawing. In post-test, all the students drew without using scale. The strategy worked here can be the deliberate instruction on drawing of biological diagrams. In an earlier study similar improvement was noticed in free-hand drawing (Dempsey and Betz 2001).

Correct Labelling, Not Crossing Label Lines, Arrows in Labelling

In pre-test only 11.1 per cent of students labelled correctly fulfilling the necessary conditions. In pre-test, 92.6 per cent of students did not cross label lines with others. Crossing labelling lines and lines which does not touch the structures being labelled confuse the reader. These all can be due to inability to follow the directions, lack of observation and most of the times it is confusion. In one drawing, it had been drawn that carbon-dioxide is given out and oxygen is taken during photosynthesis. In another instance, the drawing depicted the chest size to be increasing during exhalation and decreasing during inhalation. In another instance, the stigma was labelled as anther and anther was labelled as stigma. Arrows are given while labelling to clearly indicate the part being labelled. A significant number of students were observed to have missed this simple but important skill during labelling.

In post-test, 74.1 per cent of students learnt to label correctly and still found that 25.9 per cent of students have done incorrect

labelling. And 85.2 per cent of students have put arrows while labelling. There is 100 per cent improvement in post-test in the skill of marking lines to label. The strategies worked for this can be engaging learners in practical for close observation, marking and correction of drawing, giving immediate feedback, use of worksheets after discussion and practical. The labelling skills are very much useful as they help us in remembering the concept learnt through visual form of memory. As noted by Janice and Clement, (2008), there is a strong evidence that when learners draw diagrams with proper labelling to represent the facts, their learning stick in their mind better than pages and pages of notes. Though nearly 30 per cent students picked up this skill during the intervention, it is noticed that even a simple skill of showing arrow needs further intervention for few students among those participated in the study.

Conclusions and Future Study

From this study it can be concluded that majority of the students in Class VII lack drawing skills. Drawing of specimens enables learners to develop observational skills. This enables them to relate structure to function. Probably the recommended practical approach in teaching of biology is overlooked in syllabus coverage. This may be the reason for majority of the respondents having misconceptions. Biology teachers need to keenly supervise and guide individual learners and groups during biology instruction especially during practical sessions, so as to develop the necessary skills in them. A teacher must give intervention right from the beginning of the session so that the students achieve mastery in drawing. Same strategies used in the present study like class discussion or using audio-visual aids or assisting in group may not be useful for improving all students in the same level. Either the duration of the intervention has to be increased with the same strategies or different strategies like continuous assessment tests or combining Biological knowledge with observational skills and then illustrating it with diagrams which are properly labelled (Landin, 2015) have to be tried out for further improvement. This is all the more important because in the present situation when the classroom is converted to virtual and digital media, drawing and labelling skills which are usually picked by students through teachers' modelling are gradually reducing. Hence, it becomes necessary to achieve mastery in drawing and labelling skills so

that it leads to conceptual clarity, reduction in misconceptions, not stopping at surface learning, better performance in science and improved visual perceptual ability. Scientific skills like keen observation, problem solving, drawing and labelling, analysis, synthesis and creativity were not actually being practiced in the sampled school and the drawing of specimens during practical sessions was clearly overlooked. Hence it is recommended that there should be a continuous in-service professional development of practicing teachers and participation in workshops and conferences is required to update them on new innovations in science teaching. Such forums are also important as they enable participants to share their expertise with colleagues. Based on the experience in the field of study, some suggestions can be made for further research. Follow up studies have to be taken up to confirm the sustainability of skills over time. The present study was limited to Class VII students only. So it can be extended to other levels with other subjects. Senior secondary and college students can also be considered for future investigation. The present study may be useful to reform the curriculum for activity-based learning.

As recommended by NCF (2005), the aim of science education is to know the facts and principles of science and its applications, also acquiring skills and understanding methods and processes that lead to generation. To achieve the aforesaid objectives of teaching science, developing drawing and labelling skills can facilitate in achieving the objectives of teaching science like keen observation, problem solving attitude, and learning by discovery/ inquiry. Therefore, it can be construed that drawing scientific diagrams sharpens a student's cognitive functions by making them relate structure to function a step forward for cognitive anchoring.

References

Aggarwal, D.P. 2001. *Modern Methods of Teaching Biology*. Sarup and Sons Publishers. India, New Delhi.

Alkaslassy, E. and T. O'Day. 2002. Linking Art and Science with a Drawing Class. *Journal of College Biology Teaching*. vol. 28, no. 2.

Australian Academy of Science. 2009. *Literacy Focuses Across Curriculum Connections Units, Primary Connection Project Stage 3* from www. quality teaching (2006-2008) deewi.gov.ali.

Biological Sciences Curriculum Study (BSCS). 1992. *Biological Science: An Ecological Approach, Seventh Edition.* Kendall/Hunt Publishing Company, Colorado Springs.

Bolanle, T.D. and N.L. Soladoye. 2014. Exploring Annotated Drawing for Improving Nigerian Secondary School Students' Achievement in Genetics. *International Journal of Biology Education*. vol. 3, no. 1. pp. 2-11.

Dempsey, B.C. and B.J. Betz. 2001. Biological Drawing: A Scientific Tool for Learning. *The American Biology Teacher Issues*. vol. 15, no. 4. pp. 271-279.

Geoff, H. 2000. *Secondary Biology*. Macmillan Kenya Publishers, Nairobi.

Janice, D.G. and J.J. Clement. 2008. Effects of Student-Generated Diagrams Versus Student Generated Summaries on Conceptual Understanding of Causal and Dynamic Knowledge in Plate Tectonics. *Journal of Research in Science Teaching*. vol. 36, no. 1. pp. 39–53.

Landin, J. 2015. Rediscovering the Forgotten Benefits of Drawing. *Scientific American.* Retrieved from http://blogs.scientificamerican.com/symbiartic/rediscovering-the-forgotten-benefits-of-drawing/

Ostrogona, S. R. and E. Mulyandi. 1999. How to Be More Visual in Your Lectures or Tutorials: One Drawing is Worth a Thousand Words. In K. Martin, N. Stanley, and N. Davidson, (Eds.), *Teaching in the Disciplines/Learning in Context,* (pp. 298-301). Proceedings of the 8th Annual Learning Forum, the University of West.

Rogers, M. 2008. Learning by drawing. *Symmetry Magazine.* Retrieved from http://www.symmetrymagazine.org/breaking/2008/05/21/learningbydrawing

Wekesa, E.T. 2013a. An Assessment of How Students' Mastery of Drawing Skills in Secondary Schools Affects Performance in Biology in Bungoma West District, Kenya. *Journal of Emerging Trends in Educational Research and Policy Studies (JETERAPS)*. vol. 4, no. 3. pp. 525-533.

Wekesa, E.T. 2013b. Strategies Used By Teachers to Improve Students' Mastery of Drawing Skills and Performance in Biology in Bungoma West District, Kenya. *Journal of Emerging Trends in Educational Research and Policy Studies (JETERAPS)*. vol. 4, no. 3. pp. 473-479.

Yockey, J.A. 2001. Simple Writing Technique to Help Students Communicate the Important Science Concepts they have learned. *Science and Children*. vol. 38, no. 7, p. 3.