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Enhanced Learning through Analogy in the Teaching of Cardiovascular System

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ABSTRACT

This study examined the use of analogies incorporated in biology teaching for the topic 'transport in humans'. An action research approach was utilized, comprising both quantitative and qualitative analyses, in a 10th grade secondary school classroom setting. Parameters such as mean, standard deviation and the covariance analysis from both pre and post tests disseminated revealed that using analogy, as a method of teaching was statistically significant in improving the students' conceptual understandings and their critical thinking in constructing knowledge from their environment. The quantitative findings were qualitatively supported with the students' worksheets and outcomes from the interviews. The ability of the students to think critically was observed in the intervention. With the guidance from the teacher, students can reflect upon scientific concept that they learned by successfully bridging between the target and the analogue.

Keywords: Analogy, biology, conceptual understanding, constructive learning, critical thinking.

INTRODUCTION

Comprehending difficult concepts, principles and theories could become easier in a classroom where teaching is carried out with analogy. Analogies provide simplified learning task and interpretations from the learners' existing knowledge. Analogies make the topic/concept familiar, common and easy to understand (Tairab, 1996). According to Orgill and Bodner (2004) whenever a new concept is introduced to students, it always becomes more easily understandable to them if it is linked to something they are already familiar with and come across it in their day-to-day life. Orgill and Bodner (2004) further emphasized that

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even though students are taught using analogies to understand, recall and visualize information from the class, yet these analogies are not presented in the class as efficiently as it should have been.

Treagust and Duit (2008) assert that analogy when recalled, helps to motivate students to become enthusiastic and talkative. Applying the use of analogies in classroom also helped students to overcome misconceptions (Hanson & Seheri-Jele, 2018). Orgill and Thomas (2007) suggest that using analogy in classrooms is significant due to its essential effect in communication, problem solving and creativity. In addition, Orgill and Thomas (2007) also suggest the incorporation of analogy in the different phases of the '5E Instructional Model' that comprised of Engage, Explore, Explain, Elaborate and Evaluate. The use of analogy in the 5E instructional phases enhances an inquiry-learning environment, making it easier to explain the concept, as students are interested to explore and focus on the concept (Bybee, 1993). For example, by relating the water tower analogy to cardiovascular system, the complexity of cardiovascular system is made easy by drawing comparison to cities water tower supply (Swain, 2000).

Herr (2007) emphasizes the benefits of employing teaching with analogies (TWA) strategy while minimizing the dangers of misconception. The TWA is a model originally introduced by Glynn, Duit and Thiele (1995), which works on the mapping of shared attributes. Each step in the TWA model is important. Depending on the teacher's style in approaching the steps in dealing with the specific scientific concept, a particular use of analogy will be modified accordingly (Harrison & Treagust, 1993).

Based on Piaget's view of constructivism, involving assimilation and accommodation of new knowledge over the students' past experience, the classroom instructions can be directed towards natural phenomena, which students encounter in their daily life. Analogy can also be considered as a Velcro tape, which will allow the new information to adhere to students' prior knowledge, in a way enabling them make sense of the scientific ideas (Smith & Abell, 2008). Harrison and Treagust (1993) concluded that presenting analogies with a systematic teaching model diminishes misconceptions.

Models of Analogy in the Classroom

The general model of analogy teaching (GMAT) is a lengthy 9-step model that guides teachers to use of analogies in the classroom (Zeitoun, 1984). Assessing students' prior knowledge or general overview related to the analogical learning in general. Although this model gave an idea on using analogy in the classroom, yet it was not satisfactory the major weakness of being the complexity of measuring the analogical reasoning and identifying the cognitive complexity.

TWA model is another model proposed by Duit (1991), to guide teachers about the appropriate use of analogy and step-by-step procedure in introducing analogy as an alternative teaching strategy. It is a model that predominantly deals with analogy, based on textbooks instead of principles on pedagogy. There are six steps in the TWA model that needs to be followed in a sequence. The TWA model associates the term *target* to the new scientific concept and identifies the relevant features between the analogue and the target through mapping, and finally drawing conclusion in relation to the target and specifying the end-point of the analogy. Like the GMAT model, the TWA model also has drawbacks but these are easy to fix.

The Focus, Action and Reflection (FAR) guide enables a logical representation of analogies, and resembling itself to a more appropriate teaching arrangement with an action research approach (Harrison & Treagust, 2006). Additionally, the FAR model is based on constructivist theoretical framework. The model aimed to boost the benefits and diminish the

constraints of analogies when it is used to teach science (Treagust et al., 1994). This model consists of three phases: focus, action and reflection. The foremost phase of this model is focus. In this phase the teachers are encouraged to focus on the science content to ascertain why it is difficult. The teacher use the analogue to ensure it is familiar to the students, and the students reflect on the ideas they already have about the science concept. The second phase is action. Any similarities and dissimilarities discussed between the concept in science and the analog takes place in this phase, which is either between the teachers and students, or students and students. The purpose here is to delineate limitations of the analogy. Final and third phase is reflect. In this phase drawing a conclusion is made, and the decision is to be made here whether the analogy is clear and useful or confusing. This has to be reflected upon by an improving the analogy based on the results. When the FAR model used in classroom, it can maximize the benefits of analogy. The other advantages of the FAR model are; it is comprised only three phases and enables active participation of students thus bringing in meaningful discussions.

Types of Analogy

There are a lot of ways to classify an analogy. Dagher (1995) distinguished five different analogies namely, a) compound analogy which uses more than one source, b) narrative analogy which is a story based analogy, similar to a story telling, c) procedural analogy which gives instructions for completing a task and very similar to science experimental procedures, d) peripheral analogy which is a teacher elaborated analogy usually created spontaneously in order to support the main analogy, and e) simple analogy which is associated with the target and shows clear bridging between the target and analog.

Analogies can be classified as student or teacher centered. *Student self-developed analogies* are that created by students to express their learning experiences. The teacher plays a big role in encouraging and motivating students to find new opportunities for a more advanced conceptual understanding. Such use of analogy integrated with guided practices and inquiry learning promote new tasks and let students to employ other thinking skills. Here, the teacher only facilitates an analogy by providing an analogical situation and the students infer the analogous attributes. Thus, it enables developing critical thinking to locate the attributes (Tairab, 1996). The practice of guided inquiry with analogy also helps in a significant reduction in the gap in acquisition of science process skills between the genders (Nworgu & Otum, 2013). A *teacher-centered analogy* is usually helpful in learning new tasks and ruled by the teacher since this form of analogy is both created and presented by the teacher. The application and conceptual understanding in the learning are less effective in the teacher-centered analogy.

Duit (1991) organized analogy into four groups namely *pictorial, personal, bridging, and multiple* analogies. Pictorial analogy is one of the most common types of analogy used by teachers and textbooks. The pictorial analogies are easier to be understood by the students and to be related as an analog. While personal analogies are those students relate an abstract scientific concept to students' real world environment. Duit (1991) also claimed that pictorial analogy is more enjoyable and easily understood analogy by students as well as motivates them.

Using Analogy in Teaching and Learning of Cardiovascular System

When teaching other lessons or concepts, different analogies can be identified according to their complexity, such as simple analogies, enriched analogies, and extended analogies, (Ahmed & Cheong, 2006). Simple analogies are those of which the teachers identified the target simply as the analogue without any further effort. An example of a simple

analogy is a factory is like a cell. Enriched analogies include one or more analogies to explain the target concept. Enriched analogies are known to be the most appreciated by teachers. Lastly, the extended analogies include the inclusion of one or more analogies in order to explain a target, similar to enriched analogy but the main difference is on the use of several attributes in describing the target (Ahmed & Cheong, 2006). As teachers support the use of complex analogies by utilizing them in their teaching as a source of critical thinking for the students, the use of complex analogies would encourage student discussions and the students' participation made them learn better.

In this paper, the use of analogy to teach transport in human, also known as the cardiovascular system, is explored. Extended literature review reveals that there is limited number of published and focused studies in this field. The one and only published study is by Swain (2000), which relates the water tower analogy to cardiovascular system by drawing comparison to cities water tower supply. Swain (2000) claims that the presented analogy had successfully made the concept easier to understand. However the analogy came with a need of clear justification on the possible misconceptions that might occur as cardiovascular system is a closed system that is not affected by gravity, whereas the water tower system is an open system that utilizes gravity for water to flow downwards. Moreover, based on the complexity of the analogue, students' thorough understanding of the analogue plays a very crucial role in further thoughtfulness of the target and hence empowering the teacher in using the appropriate analogy. It is therefore the responsibility of the teacher to identify an appropriate analogue familiar to the students. This paper discusses extended type of analogy that contributes and takes into consideration various analogies in improving the teaching and learning of the cardiovascular system topic.

It should be emphasized again that there is paucity in the literature on the use of analogy to teach cardiovascular systems except for the water tower analogy described by Swain (2000). Therefore, the current study provides support for Swain's study on the effectiveness of using the water tower analogy for the teaching of cardiovascular system.

METHODOLOGY

This study employed an action research design approach incorporating the use of the mixed-methods (quantitative and qualitative) analyses. The quantitative analysis measurement included the analysis of pre and post tests using statistical methods. The study was further driven using qualitative analysis of guided worksheet questions, opinion polls and interviews. The interviewees were chosen based on the students' performance scores in their pre and post-tests, ranging from the high ability, low ability and average ability student participants. Figure 1 is the graphic representation of the methodology followed during the study of action research. Two research questions that guided this study are as follows:

1. What is/are the effect(s) of teaching biology using analogy on the achievement of 10^{th} grade students on the concept(s) of cardiovascular system?
2. Does the analogy enhance the students' critical thinking in constructing knowledge from their learning?

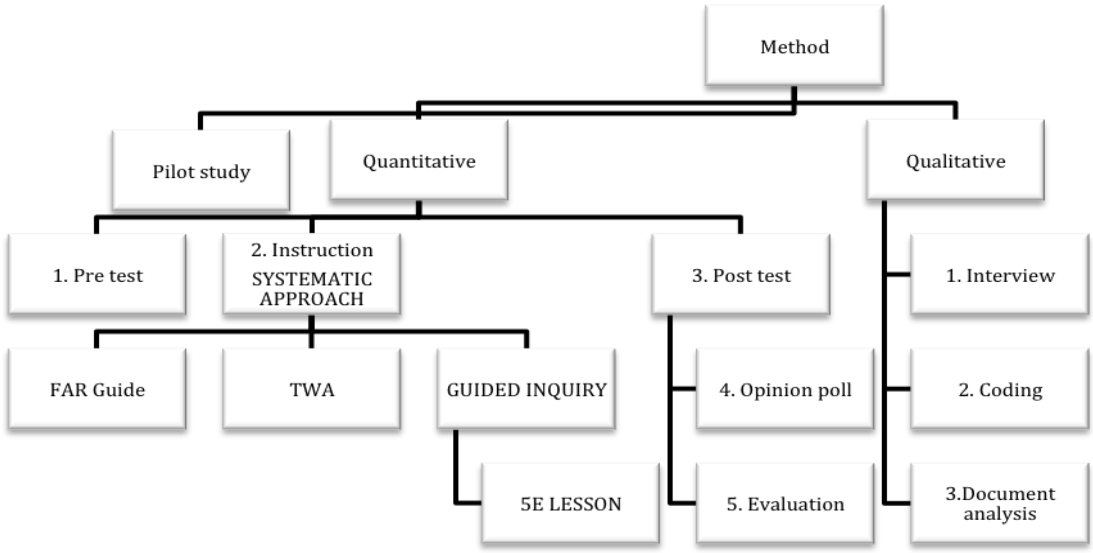

Figure 1. Methodology of the action research

a) Sample

The 21 student participants were from one 10th grade class. There were 14 to 15 years old students with mixed learning ability. The number of girls-to-boys was found to be in the ratio of 13:8. Culturally, majority of the students were local Bruneians and few being Chinese descendants staying in Brunei. English language was a secondary language for these students. The sample site was a secondary school located in the Brunei-Muara district.

b) Instruments

The test papers were categorized into two sections: multiple choices questions and essay-type structured questions. Each section was 15 points, thus totaling to 30 points for each test paper. An opinion poll was also distributed to assist in both quantitative and qualitative analyses. Student participants were interviewed based on the post-test performances; two students from each achieving categories (high, medium and low) were interviewed.

The validity of the test paper was checked, followed by content reliability by a specialist of the subject biology, using modified questions based on the General Certificate of Education Ordinary syllabus for Biology (syllabus code 5090). A pilot study of the test paper was carried in determining the difficulty index and reliability of the test through SPSS packet program.

c) Data Analysis

Students were taught the biology topic on ‘Transport in man: The human cardiovascular system’. Several subtopics were chosen such as double circulation, the flow of blood around the body, blood components and the working of valves in a vein, different chambers of heart, and rejection of organ by the body during tissue transplant. First the pre-test data was collected to determine students’ understanding about the content taught without the use of

analogy. Then, the same scientific concepts were dealt with the help of simple analogies prepared by the researchers.

After the pre-test, the same topics are taught again with the help of systematic approach to analogy. The FAR guide and the TWA method incorporated in the 5E lesson plans. Teacher facilitated the students in forming the analogy between the target and the analogue by using these lesson plans. During the intervention, the subject of cardiovascular system was taught through analogy method. All the activities were done in the teaching environment related to practicing analogy, PowerPoint presentations, and lesson plans incorporated into 5E learning cycle. The different types of analogies were prepared after a careful study on the understandability, plausibility, and prolificacy of the conceptual understanding. The same test was applied as the post-test to determine any changes in student's conceptual understanding. Sample t-test for independent and dependent groups in SPSS packet program was used to analyze the data obtained.

FINDINGS

The pre and post-test scores were evaluated to observe changes on the students' conceptual understanding on the lesson of cardiovascular system before and after the intervention with analogy. Statistical test of dependent group's t-test was applied in determining whether there is any significant difference between the pre- and post-test groups. The test results were presented in Table 1.

Table 1. *Dependent group's t-test in analyzing pre- and post-test scores on the effects of teaching using analogy*

Group	N	Mean	S	SD	t-value	p-value*	ETA^2
Pre-test	21	11.33	4.36				
				3.35	11.64	0.001	0.74
Post-test	21	19.86	3.44				

*p<0.05

As seen in Table 1, the group's average score of the pre-test is 11.33 with a standard deviation of 4.36, whereas the average score of the post-test is 19.86 with a standard deviation of 3.44. The student t-test value achieved was t=11.64, with a p-value less than 0.001. Since the p-value is less than 0.05 implies that there is a significant difference between the two test scores. With the increase of the post-test average scores, it also depicted that teaching biology concept using analogy does have a positive impact.

Consequently, an independent group t-test was carried out to determine if the understanding towards the taught scientific concept on the topic of cardiovascular system before and after the intervention of analogy differed according to gender. The results for the pre-test are given in Table 2 and the results for the post-test presented in Table 3.

Table 2. *Independent group t-test in comparing the pre-test scores by gender*

Gender	N	Mean	S	t-value	p-value	ETA^2
Male	8	11.00	5.59			
				0.144	0.887	0.001
Female	13	11.30	3.92			

As seen in Table 2, pre-test average scores for both male and female students on the topic of cardiovascular system before the intervention indicates a close distribution to each other. The students' pre-test scores t=.144 with p-value of 0.887 indicates that the students' understanding of cardiovascular system before the intervention with analogy is significantly similar to each other regardless of the gender differences.

Table 3. *Independent group t-test in comparing the post-test scores by gender*

Gender	N	Mean	S	t-value	p-value	ETA^2
Male	8	21.00	4.20			
				-1.026	0.318	0.055
Female	13	19.30	3.11			

Similar to earlier findings, the male and female students' post-test average scores does not indicate any significant difference as indicated by the p-value of more than 0.05 in Table 3. The average score obtained by the male students is 21.0, whilst the female students scored 19.3. The result obtained suggests that students' understanding towards the taught biology concepts before and after the intervention is equal for both genders.

Concurring with the findings by Orgill and Bodner (2004), the findings from this study suggests the use of analogies may be applied when there are difficulties and challenges in the target concepts, and when new target concepts are introduced that cannot be visualized. Accordingly, when an analogy is used in a lesson it enhances students' interests and attitudes in their studies (Al-Hinai & Al-Balushi, 2015; Paris & Glynn, 2004).

Lemke (1990), and Hanson and Seheri-Jele (2018) asserted that the students would pay more attention to an analogy, which are familiar to them compared to unfamiliar contexts containing scientific terms. Similarly, Orgill and Bodner (2004) supported that most students preferred the use of analogies by their teachers in explaining or introducing concepts that were complex. Additionally, these students found the use analogies in learning as entertaining and they were able to retain and understand the topic. Figure 2 shows questions posed to the participating students in this present study after experiencing lessons with the use of analogy.

Name:_____ Class:_____

Unit 7:_____ Date: _____

Answer the following in only **Yes or NO**

No		Yes / No
1	From the analogies during the lesson on Transport in Human, do you feel like using analogy more often for your future lessons?	
2	Did the use of the analogy in your lesson of "Transport in Human" help increase your understanding of the topic?	
3	Has the analogy been helpful to you in removing your doubts (not sure of) or other prior ideas about this topic?	
4	Were you able to visualize (as in see) the concepts while doing the study with analogy? For example, plumbing system of your house is like the cardiovascular system of your body.	
5	Would you recommend this use of analogies to your teachers and friends?	

Figure 2. Questions posed to participating students

According to data from the opinion polls, majority of the participating students preferred lessons with the use of analogy (see Table 4).

Table 4. *Overall opinions of the participating students on the use of analogy in learning*

Responses	Q1	Q2	Q3	Q4	Q5
Yes	16 (76%)	16 (76%)	14 (67%)	13 (62%)	15 (71%)
No	5 (24%)	5 (24%)	7 (33%)	8 (38%)	6 (29%)

Figures 3, 4a and 4b are samples of the students' worksheets that resulted from the use of analogy. The worksheet in Figures 4a and 4b required students to sketch how the highway compares with the blood in the blood vessels of their body. The worksheets also explored students' ability to produce the illustrations entail a high order of thinking. From the responses and the sketches obtained, all three students displayed the ability to think critically, and subsequently categorized as high achieving students.

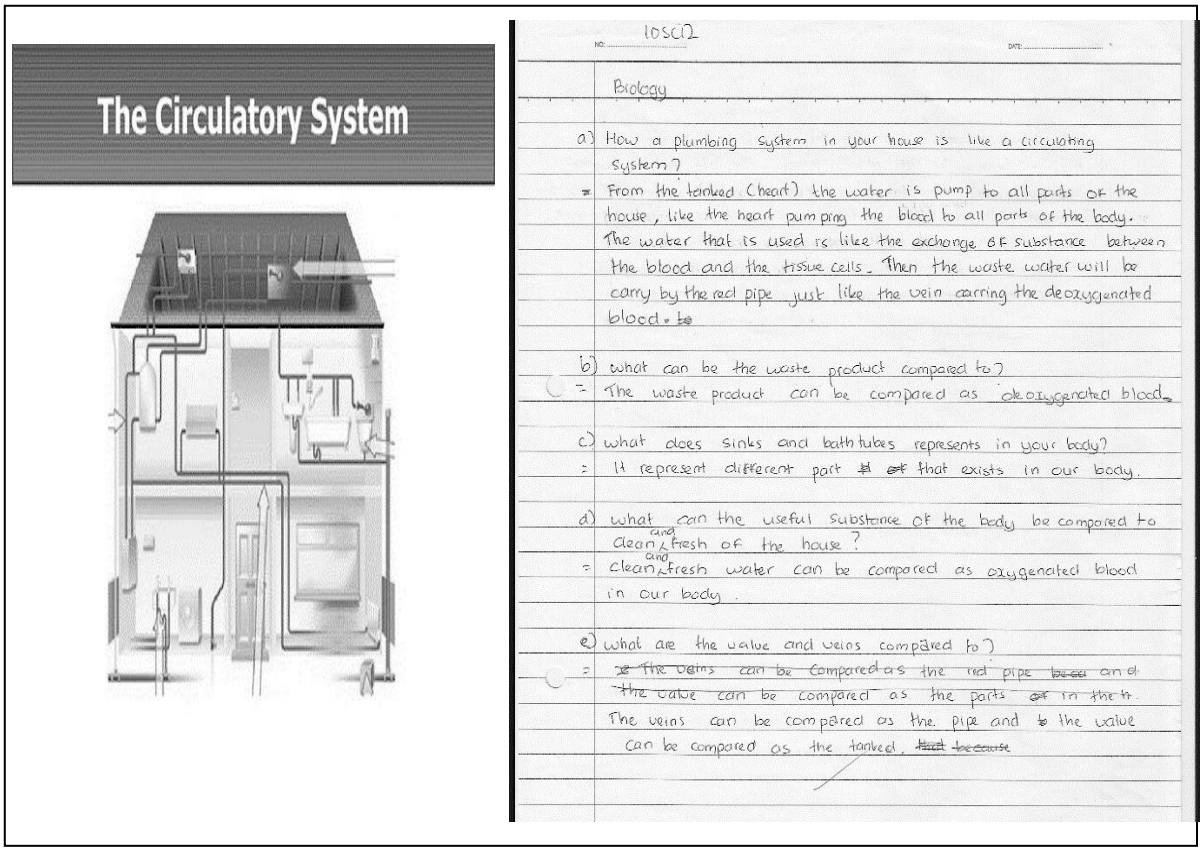

Figure 3. Responses from Student A on the comparison of plumbing system of a house to that of blood transport system of human body

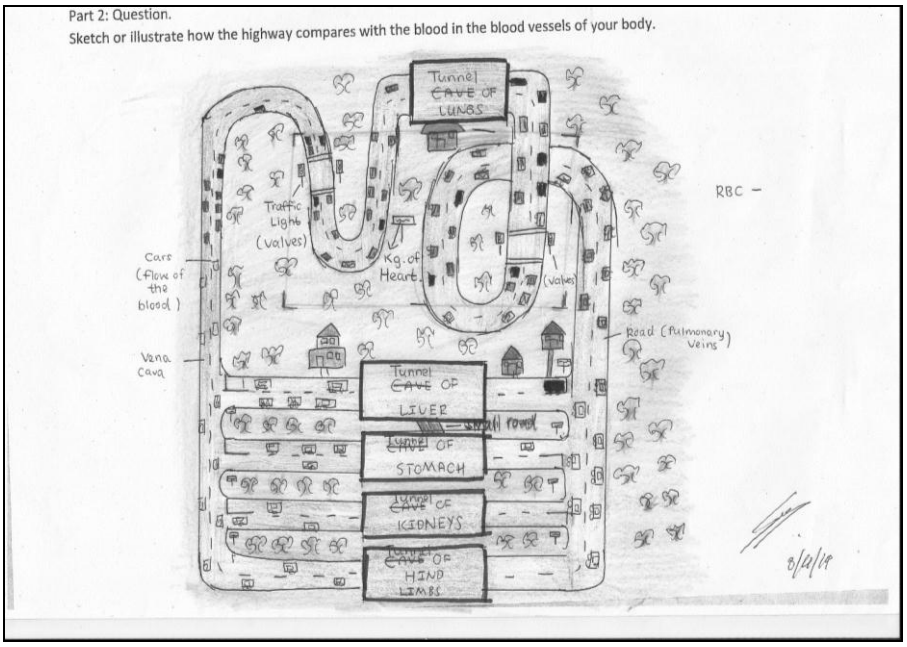

Figure 4a. Sketches made by Student B in contrasting the 'road highway' with regards to the blood vessels of the body

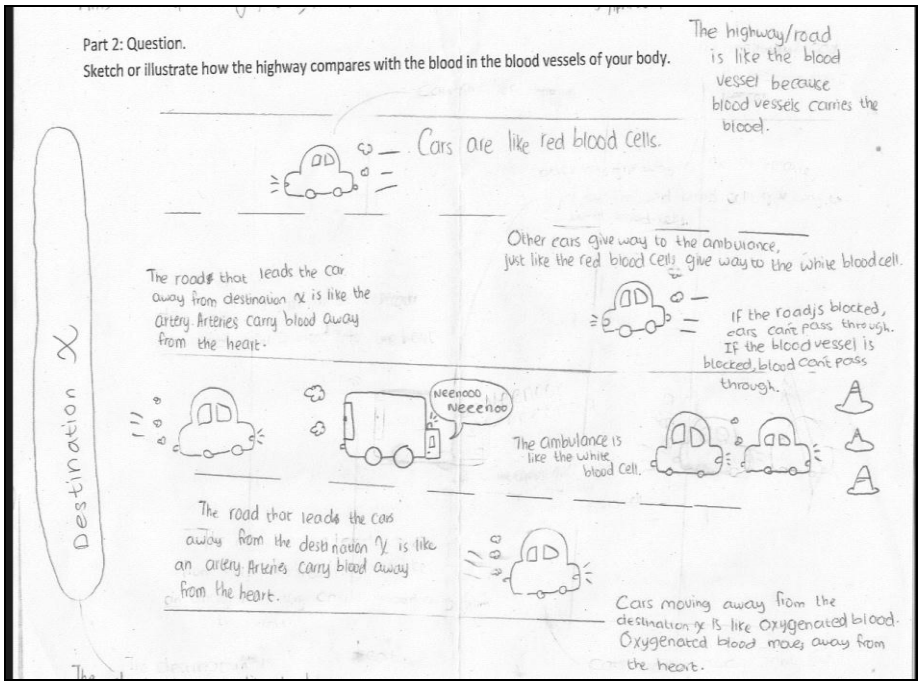

Figure 4b. Sketches made by Student C in contrasting the 'road highway' with regards to the blood vessels of the body

Upon interviewing two of the high achieving students, they stated that they enjoyed learning with using analogies. One of the students further stated "*I found it easy to relate the target from the second analogy onwards. At first when it was introduced I found it was difficult and confusing, but later on as more of analogies were compared I found it was fun. I was able to compare the circulatory system of the human body to the plumbing system of the house*". However, the students who where categorized as medium achievers said they did not like analogy. They preferred to study without using a lot of analogy and getting notes from the teacher.

The students' answers during the interview were also analyzed with their test papers for their explanations on the biological concept of cardiovascular system. The important finding obtained from the study is the development of critical thinking in students when they were asked to illustrate an analogy in their own words.

CONCLUSIONS

The use of anology in teaching the studied concept was found to instigate understanding and critical thinking in students as compared to the convetional teaching method. Another important aspect noted was that students are able to grasp analogies easily when discussed in groups. For most of the students, they were able to associate the anlogue to the target by differentiating and comparing different attributes. There were no observable misconceptions that emerged from this intervention, which could be rectified by discussions in the classroom itself. The remarkable surge in the scores of the post-test from the pre-test showed that analogies used in the intervention were effective in contributing understanding of the concepts.

It was also found that students do think critically and creatively when illustrating analogy. Students tend to be attentive as well as enjoyed learning the topic when it was discussed as these easily relates to their surrounding. Nevertheless, the students' English proficency is also very much important in order to actively take part in the discussions relating the target to the analogue. Therefore, trained teachers with the proper channel of introducing analogy may able to boost the students' overall understanding.

Effectiveness of using analogy in promoting students' understanding is positively taken in to enhance students' critical thinking in constructing knowledge from their environment. Implementing analogy for the first time to a class was proven to be challenging, however, with guidance and help from a trained teacher, its use could be effective towards the target concept by accommodating it in teaching techniques successfully. The findings showed that analogy resources do not need to be from textbooks. Resources can also be modified to students' need in the classroom. This study also throws light on the fact that students understand those analogies better with which they are more accustomed to in their day-to-day life.

The ability of the students to think critically was also studied during this intervention. It was touched upon the fact that students with guidance from the teacher can reflect upon scientific concept to be learnt by successfully bridging between the target and the analogue. This ability of critical thinking will go a long way in their reasoning and analyzing skills in the future.

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