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The Effectiveness of Using Dynamic Visualization in Natural Science Learning to Improve Students' Understanding in Junior High Schools

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Abstract. Visualization can support an instructional process. Visualization consists of all types of nonverbal illustrations. The very rapidly computer technology enables the development of multimedia learning environment. This research was aimed at describing the effectiveness and attractiveness of the use of dynamic visualization in an instruction on transportation system and excretion in organisms. Sixty four students of grade 8 who consisted of 36 males and 28 females were used as the subjects of the research. The data of the research were collected in the form of pre-test and post-test scores in the students' understanding of transportation system and excretion in organisms and in the attractiveness of the use of dynamic visualization in the instruction. Statistical test showed that the mean of the comprehension test before the use of dynamic visualization differed significantly from that after the use of dynamic visualization and that dynamic visualization was attractive to be used in the instruction. Hence, it can be concluded that dynamic visualization can enhance students' understanding.

Keywords: animation; dynamic visualization; multimedia; science instruction, Understanding;

INTRODUCTION:

Management of learning environment is important to make students want to learn and to make it easier for them to learn. One of the characteristics of environmental management is the participation of the students as the subjects who learn (Degeng, 2013). The development in computer technology makes various multimedia learning environments development possible. Multimedia make it possible to combine media such as picture, text, and sound through different modality channels (Horz & Schnotz, 2010). Media variations such as text, graph, audio, and video can deliver learning contents in an attractive way for teachers and students for use in an instruction. The strategy of the use of the media is an important part in an instruction. Multimedia present materials through words and pictures (Mayer, 2009). Computer-based technology such as electronic communication system, dynamic model and visual system equipment, multimedia environment are some examples which can be integrated in a classroom to strengthen students' thinking and learning abilities (Angeli & Valanides, 2004). An important point in the application of technology in instruction is to facilitate the teacher to teach. Heinich, et al, (2002) clarifies that technology plays an important role in education. When technology is used well in an instruction, students will become more interested and challenged in learning (Baytiyeh & Naja, 2010). Technology and media that are appropriate and

specifically designed can contribute to an effective instruction for the students and help them to attain a high learning achievement. A shift in education paradigm as the consequence of the introduction of constructivist perspective in education has changed a teaching era into a learning era (Reigeluth, 1999). Multimedia technology development opens an opportunity to create interactive instructional materials that support the instruction. Technology development makes it easy to design instructional media to bring real phenomena in the form of videos of facts and a daily life into the classroom (Mayer, 2009).

Now the learners are the consumers of visual information (Lundy & Stephens, 2015). Visualization is a tool to support an instructional process (Hoffler, 2010). Visualization is defined as all kinds of non-verbal illustrations (symbolical, such as graph, and picture like diagram, animation) (Hoffler, 2010). Visualization is a specific form of external representations meant for communicating information by using this information visual-spatial layout which is processed in visual sensory system (Scheiter, Wiebe, & Holsanova, 2009).

Some studies indicate the difficulty in learning and instructing in science since it is related to abstract processes and phenomena (Barak & Dori, 2011). The studies that discuss whether dynamic visualization helps students in understanding dynamic phenomena has produced positive and negative answers (Schnotz & Rasch, 2005). In science instructions, dynamic visualization is used to describe, explain and predict scientific process (Barak & Dori, 2011). Dynamic visualization is promising enough to be used in science instruction at elementary and high schools, even at universities (Barak & Dori, 2011). Visualization is a basic form of cognition and plays an important role in student's imaginative ability and activities from navigating, memorizing, and problem solving (Barak & Dori, 2011). Dynamic visualization such as animation and video contain a series of frames (Ainsworth & VanLabeke, 2004). Dynamic visualization is appropriate for presenting continuous changes in space and time such as in a process, mechanism, and motion (Tversky, B., Morrison, J. B., & Betrancourt, 2002).

At this time, dynamic visualizations such as animation and video are more frequently being used to present a process. For instance, they are used to show the formation of light (Mayer & Chandler, 2001) and the pumping of blood through the heart (de Koning, Tabbers, Rikers, & Paas, 2007). One of the reasons why it is frequently used in an instruction is that people think that students will find it much easier to understand the lesson and render it unnecessary to imagine or conclude a motion from a static visualization (Hegarty, Kriz, & Cate, 2003). The results of the studies showed that by efficiently giving the students external visual representations, it can build internal visual representations and enhance their learning achievement (Barak & Dori, 2011). The use of external visual representations such as dynamic visualization can increase understanding of the students' concepts, modeling abilities, and visual abilities (Barak & Dori, 2011). Dynamic visualization that is based on computer is an effective equipment to use in an instruction of science to enhance understanding of some different concepts in science (Ali & Ambusaidi, 2017). A dynamic visualization helps conceptualize abstract concepts which may be difficult for the students to understand (Ali & Ambusaidi, 2017). Dynamic visualization facilitates students to be involved actively by controlling the students in starting, stopping and recalling information that is wanted. (Wichmann & Timpe, 2015).

The underlying theory of an instruction based on visualization is cognitive theory. Cognitive theory that is rooted in information processing theory is the basis of visualization development. The basic idea from cognitive load is that cognitive capacity in the working memory is limited, so that if there is too much load, then learning will be hampered (de Jong, 2010). The three relevant principles about human information processing which come from studies in cognitive science are as follows: the principle of Dual Channels which states that a human has separate channels to process verbal materials and pictorial materials. (Paivio, 1986). The principle of Limited Capacity which states that a human can only process a little information in each channel at a time (Baddeley, 1986). The principle of Active Processing which states that meaningful learning occurs when a human is involved in appropriate processing during the learning process, which includes attending to relevant information, mentally arranging it into a coherent structure, and integrating it with other structures and with knowledge that has been activated from the long

term memory (Mayer, 2009). Based on Cognitive Theory of Multimedia Learning (CTML), the model consists of two channels, namely, verbal and image channels, three memory storages, namely, sensory memory, working memory and long term memory, and five cognitive processes, namely, selecting words, selecting images, arranging words, arranging images, and integrating them **(**Mayer, 2011**)**. The use of this Cognitive Theory of Multimedia Learning (CTML) has shown a significant contribution in learning **(**Mayer, 2014).

In the research we have studied visualization plays as important role in instruction. In detail, the research questions are: 1) whether there are is effectiveness of the use of dynamic visualization in science at the eighth grade on transportation and excretion in organisms, and 2) whether there are is attractiveness of dynamic visualization used in science at the eighth grade on transportation and excretion in organisms.

The focuses of this research were as follows: 1) to find out the effectiveness of the use of dynamic visualization in science at the eighth grade on transportation and excretion in organisms, and 2) to find out the attractiveness of dynamic visualization used in science at the eighth grade on transportation and excretion in organisms.

METHOD

This research used one group pre-test post-test design (Ary et al., 2010). This design was selected to find out an increase in the students' understanding of transportation and excretion in organisms after using dynamic visualization in learning. This research involved students and teachers of science at junior high schools in an effort at enhancing understanding in science instruction at the eighth grade on transportation system and excretion in organisms.

There were two types of variable in this research: an independent variable and a dependent variable. The independent variable was dynamic visualization and the dependent variable was learning achievement in understanding. In addition to the variables, there were other variables which needed to be controlled. They were 1) time of the instruction, 2) the attitude and seriousness of the students and the teachers in the instruction, and 3) the expressed interactions during the instructional activities. The three variables were assumed to remain constant so that it was assumed that they did not had any significant effect on the dependent variable or understanding.

Teacher qualification was an important part in this research. The teacher was expected to facilitate the students to do instructional activities using dynamic visualization to ensure that the effect that was resulted was really the effect of dynamic visualization only, not the effect of different teachers' strategies. To avoid biases from the teacher qualification, the same teacher managed the instructional activities both in class VIII A and class VIII B.

The research involved two teachers who had skills in using computer with relatively the same academic abilities (having at least five years in teaching science on this topic). Prior to the experiment stage, both of the teachers were trained to manage instruction using dynamic visualization.

The sample consisted of the students of State Junior High School 4 Singaraja, Indonesia (Sekolah Menegah Pertama Negeri 4 Singaraja, Indonesia). The subjects were class VIII A and class VIII B with the total number of 64 students, consisting of 36 males and 28 females.

The ADDIE model was used to develop dynamic visualization. The ADDIE model consists of analyze, design, develop, implement, and evaluate stages (Branch, 2009). The stages can be described as follows. a) analyze, the analysis stage is a process to define what to be learned by the students, namely, to do problem identification, need analysis, and environment analysis. Thus, the media produced are based on the learner characteristics or profile, the identification of gap, identification of need, and analysis of task in detail; b) design, the designing stage consists of the making of storyboard and visualization; c) develop, the development stage is the process of bringing the design into a reality. It means if the design needs one software in the form of multimedia, the multimedia has to be developed; d) implement, the implementation stage is the real step toward the implementation of the instructional system being produced. It means that at this stage, all that have been developed are installed or set in such a way in accordance with their role or functions to be able to be implemented; e) evaluate, the evaluation process is aimed at seeing whether the instructional system being developed is successful, in accordance with the

expectation or not. The evaluation stage can occur at each of the previous four stages above. The evaluation which occurs at every stage of the four stages is called formative evaluation, since the purpose is to help in a revision.

Dynamic visualization that was developed followed the principle of spatial contiguity (words and graphs which are related are presented close to each other on paper or screen), the principle of coherence (extraneous materials are discarded instead of being discarded at the time when they are inserted), the principle of segmenting (a complex lesson is presented in manageable parts) and the principle of multimedia (an individual learns more effectively from words and pictures than just from words (Mayer, 2014).

Before being implemented in the instruction, the dynamic visualization that was developed was validated by media and material content experts and was tried out to students. The data collected in the dynamic visualization try-out were the data from the material content and media experts, and the responses about the attractiveness of the dynamic visualization developed. The data collection instruments were in the form of evaluation sheet for the material content and media experts and questionnaire sheets for the subjects of the individual try-out, the small group try-out, and field try-out.

The result from the material content validation by the material expert showed that the mean score was 3.75 (good) and the media validation by the media expert showed that the mean score was 4.25 (very good). On the whole, the quality of dynamic visualization developed falls into good category. The result of the individual try-out showed that the mean score was 4.15 (very good) and that of the field try-out 4.12 (very good). From the try-out, it can be seen that the students gave very good responses to the dynamic visualization developed. Hence, the multimedia product of dynamic visualization was viable for use in the instruction.

The instrument used to measure the variable of the learning achievement in understanding was a comprehension test and the instrument for measuring the attractiveness of the dynamic visualization was a questionnaire. The test was designed to measure the students' understanding of transportation system and excretion in organisms. The comprehension test was in the form of multiple-choice test. The comprehension test for the pre-test was the same as that for the post-test but the numbers of items and the correct options were made dissimilar. The procedure of the comprehension test was done through the following steps: 1) identifying basic competencies, 2) identifying indicators of learning achievement, 3) formulating the objective of instruction, 4) putting the test items made into the test matrix, 5) writing test items, 6) writing assessment rubric, 7) expert judgment, 8) field try-out, 9) analyzing the result of the field try-out, and 10) finalizing the writing of the instruments.

The content validity of the comprehension test was done by content expert and a teacher. The content expert and the teacher were given a set of instruments consisting of: item matrix, comprehension test, and assessment rubric. The result of validation for the comprehension test showed that all of the test items of comprehension fell into good category. After the test of comprehension was validated by expert, the test was tried out. The number of students involved in the test try out was 150 students. The result of test items try out done was used to determine the difficulty index, the discriminating index, and reliability of the comprehension test.

The results of try out show that the number of items which met the difficulty index and discriminating index was 40 items with Alpha Cronbach of the comprehension test of .78. Before the experiment was conducted, the researcher did a series of activities as the preparation steps with the following sequence: 1) writing the instruments; 2) developing dynamic visualization; 3) conducting the try out of the instrument and the try out of dynamic visualization; and 4) training the teachers involved in the study in the instructional scenario.

During the experiment, the procedure followed are as follows: 1) all the subjects were given the pre test; 2) after finishing the pre test, treatment started on the following day. The giving of the treatment by dynamic visualization was done for 10 meetings, and 3) after giving the treatment, the subjects were given a post test. This research investigated the use of dynamic visualization in science at class VIII on transportation system and excretion in organism. The sequence of instructional activities during the ten meetings is as follows.

Table 1. Sequence of Instructional Activities

Meeting	Dynamic Visualization	Time Allotment
I	Transportation system in plant	3 x 40 minutes
II	Transportation system in human	2 x 40 minutes
III	Blood circulation organ	3 x 40 minutes
IV	Human respiration organ	2 x 40 minutes
V	Disorder in human respiration	3 x 40 minutes
VI	Excretion system	3 x 40 minutes
VII	Excretion system in kidney	2 x 40 minutes
VIII	Excretion system in lungs, liver and skin	3 x 40 minutes
IX	Disorder in human excretion system	2 x 40 minutes
X	Living pattern to maintain excretion system health	3 x 40 minutes

To analyze the data of the research, paired sample t test was used. Data normality test was done before the paired sample t test to test the normality of the data Kolmogorov-Smirnov test method was used. The normality test of the data shows that the data were normally distributed ($p > .05$), hence the analysis of the data could be continued with paired sample t test.

RESULTS AND DISCUSSION

Result

To test whether there was an increase in the students' understanding of transportation system and excretion in organism after using dynamic visualization, paired sample t test was used. The analysis of paired sample t test was used to compare the pre test score and post test score. The result of the analysis showed that there was a different in the pre-test and post-test for mean score. The result of pre-test and post test mean score presented in Table 2.

Table 2. Result of Pre-test and Post-test

	Pre-test	Post-test
Mean	20.15	31.38
Std. Deviation	5.70	2.53

To find out the difference in comprehension test means before the use of dynamic visualization and after the use of dynamic visualization, paired sample t test was used. Based on statistically, the mean score of the comprehension test before and after the use of dynamic visualization differ significant ($p < .05$). Therefore, it can be concluded that there is a difference in mean for the comprehension test before and after the use of dynamic visualization.

The result of questionnaire given to students about the attractiveness of dynamic visualization showed the means of 3.85 (very attractive).

The comments given by the students about the attractiveness of dynamic visualization dynamic are as follows: visualization given was very good and interesting, easy to understand and with the use of dynamic visualization multimedia, students understand the material more clearly than by reading books and my interest in learning increases because of the dynamic visualization multimedia.

Discussion

The results showed that dynamic visualization could improve the students' understanding and it was very interesting to be used in instruction in Science for Class VIII on transportation system and excretion in organism. The attractiveness is closely related to the attractiveness of the science (Degeng, 2013). This attractiveness caused the students to want to learn the subject. The strategy in organizing and delivering the instruction plays an important role in showing the attractiveness of the subject (Degeng, 2013).

The increase of the use of computative technology makes it possible to present dynamic visualization such as video and animation. Learning from computer-based visualization has become the main topic recently (Kühl, Scheiter, Gerjets, & Gemballa, 2011). Some studies show that computer-based visualization can help students to understand science concept (Chang & Linn, 2013). With computer-based visualization, students can get feedback and restate the knowledge obtained (Zhang & Linn, 2011). Computer based dynamic visualization is an effective tool used in science to improve concept understanding in different science concepts (Ali & Ambusaidi, 2017).

The use of dynamic visualization in learning can facilitate the understanding about transportation and excretion system. The benefit of using dynamic visualization can be explained in two aspects, namely a) reality level conveyed through dynamic visualization; and (b) the intensity of students' involvement in exploration. Those two aspects that become the benefits of using dynamic visualization can be elaborated as follows. First, for the students to be able to understand a lesson they need to be actively involved (Ashkenazi & Weaver, 2007; Baser, 2006) in the real learning environment and given the opportunity to manipulate objects used in it. The learning which starts from real experience (contextual) and concrete evidence can improve deeper understanding (NRC, 2002). The use of dynamic visualization in learning has the advantage in presenting the phenomenon. Second, the use of dynamic visualization intensifies students' exploration and deeper understanding about the case given. Students can repeat the observation, have time to explore information and discuss the materials in depth. The intensity of students' active involvement in learning (learning engagement) contributes to the improvement of concept understanding. This finding is in line with what has been reported by So & Kong (2008).

This research shows that the use of dynamic visualization can improve the students' understanding about transportations system and excretion in organism. Some studies got similar results (Lin & Dwyer, 2010; Sudatha, Degeng, & Kamdi, 2018; Wu, Lin, & Hsu, 2013). According to (Ali & Ambusaidi, 2017), dynamic visualization helps the students in conceptualizing abstract concepts that might be difficult to be understood by the students. Dynamic visualization can present scientific process and the changes in the process can be observed (Wichmann & Timpe, 2015). Dynamic visualization facilitates active students' involvement through students' control such as: the students can start, stop, and re-present the information that they want (Wichmann & Timpe, 2015). Thus, the results of this research are in line with the previous findings.

CONCLUSIONS AND SUGGESTIONS

The results of this research show that dynamic visualization can improve the students' understanding of the material about transportation system and excretion in organism and is interesting to be used in instruction. This research was limited to the effectiveness and attractiveness of the use of dynamic visualization in science at the eighth grade with the topic: transportation system and excretion in organism. The next research can be done to measure the efficiency in the use of dynamic visualization at school with more subjects and different topics. The suggestion to the researchers, teachers, and instructional designers is that they should use dynamic visualization in instruction. The combination of the use of visualization in construction and students' characteristic needs to be explored in the future.

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