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# THE EFFECT OF VISUALIZATION TYPE AND STUDENT SPATIAL ABILITIES ON LEARNING ACHIEVEMENT

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**Abstract.** *Students' spatial ability plays an important role in instruction with dynamic and static visualizations. This research was aimed at describing 1) the difference in learning achievement between the students who learned from dynamic visualization and static visualization, 2) the difference in learning achievement among students who have high spatial ability and those who have low spatial ability, and 3) the interaction between type of visualization and spatial ability on learning achievement. This research used the non-equivalent control group quasi-experimental design. The sample consisted of 115 eighth grade students in Singaraja, Indonesia. The data were collected by learning achievement test and Paper Folding Test. The data were analyzed using ANCOVA. The results showed that:1) there was a significant difference in learning achievement between the students who learned from dynamic visualization and static visualization; 2) there was a significant difference in learning achievement between the students who have high spatial ability and those who have low spatial ability, and 3) there was no interaction between visualization type and spatial ability on learning achievement. Therefore, the different combination of the types of visualization and sequence of presentation and relation with individual characteristic can be elaborated more in the further research.*

**Keywords:** *dynamic visualization, learning achievement, science instruction, spatial ability, static visualization.*

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## Introduction

Technology can provide more ways of making students learn actively in improving learning achievement in science and in promoting scientific ideas. Now students become visual information consumers (Lundy & Stephens, 2015). According to Linn & Eylon (2011), visualization which uses technological development makes it possible for the students to explore phenomena which are minute (molecule), quick (electron), abstract, or solar system by observing them directly. Learning from computer-based visualization has become the main topic in these last few years (Kühl, Scheiter, Gerjets, & Gemballa, 2011).

The potentiality of advanced technology to design instruction such as in visualization gives enthusiasm to instructional designers and practitioners. Visualization has long been used in its historical development, it has long been used in instructional materials, and researches in the past have shown that it is very easy to adapt a visualization to a new technology and in its turn, it can improve learning achievement. Visualization is a key component in multimedia-based instruction. It is defined as all types of non-verbal illustrations (both symbols, like as graph, and images of realistic diagram, or animation) (Hoffler, 2010).

Visualization has an important role in instruction (Gilbert, 2005). Visualization in instruction is a visual-spatial representation which is meant to improve instruction (Mayer, 2011). It has some roles in instruction (Smaldino, et al., 2005), i.e., 1) to provide concrete references for ideas, 2) to motivate students by improving attention, maintaining attention, and arousing emotion, 3) to simplify information which is difficult to understand, 4) to help in organizing materials by illustrating relations among elements in the form of a diagram, and 5) to provide multiple channels or multimodality information to facilitate understanding. Visualization, especially the computer-based visualization is largely used in instruction which stresses student understanding (Roblyer & Doering, 2010).

Learning from computer-based visualization has become the main topic in these last few years (Kühl, Scheiter, Gerjets, & Gemballa, 2011). With the intensive use of digital technology, it is possible to present not only static visualization but also dynamic visualization such as video and animation

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(Kühl et al., 2011) computerized visualization and animation are the promising methods to promote science instruction at elementary school, high school and university (Dori, Barak, & Adnir, 2003). Computerized visualization and animation are used in research and instruction to describe, explain and predict scientific phenomena (Dori & Belcher, 2005). Studies show that one of successful methods to improve students' science learning motivation is by integrating visualization and animation into their learning process (Barak & Dori, 2011). Results in researches on instruction show that instruction with visualization can improve learning achievement (Lin & Dwyer, 2010; Nguyen, Nelson & Wilson, 2012; Wu, Lin, & Hsu, 2013; Yarden & Yarden, 2010).

Now dynamic visualization can be readily incorporated into computer-based instructional environment (Brucker, Scheiter, & Gerjets, 2014). Due to continually rapid developing computer graphic technology, computer-based learning environment can easily be enhanced with different visual presentation formats (Brucker et al., 2014). Applying dynamic visualization in computer-based learning environment also makes it possible to visualize changes in objects that occur in outer space (Rieber, 1990).

Dynamic visualization is an important instrument to present scientific processes that can be observed, such as mechanical mechanism (Hegarty, 2004). Learning from dynamic visualization can become a challenge. Continuous and rapid changes put a heavy demand on the student's working memory (Hegarty, 2004). Now dynamic visualization such as animation and video are more and more used to present a process. For example, animation is used to show the arrangement of light (Mayer & Chandler, 2001), the pumping of blood through the heart (de Koning et al., 2010). One of the reasons why dynamic visualization is frequently used in instruction is because people think that it will make it easier for the students to understand the dynamics of a process than through imagining or concluding the motion from a static visualization (Hegarty et al., 2003).

In science education, dynamic visualization is used to describe, explain and predict scientific process (Barak & Dori, 2011). Computer-based dynamic visualization is an effective instrument to be used in science instruction to improve science learning achievement in various science concepts (Ali & Ambusaidi, 2017). Dynamic visualization is promising enough to be used in science education both at elementary school, high school and university (Barak & Dori, 2011). Dynamic visualization is an interesting part in science instruction since it presents scientific process (Wichmann & Timpe, 2015). Visualization is the basic form of cognition and plays an important part in the student's image forming ability and activities starting from navigation, memory and problem solving (Barak & Dori, 2011). Different from static visualization, dynamic visualization can present scientific process and from which changes can be observed (Wichmann & Timpe, 2015). Some researches indicate difficulties in science teaching and learning process since they are related to abstract processes and phenomena (Barak & Dori, 2011). Computer-based dynamic visualization is an effective instrument to be used in science instruction to improve concept understanding in various different science concepts (Ali & Ambusaidi, 2017).

Some researches do not find that dynamic visualization is superior to static visualization (Lewalter 2003; Mayer et al., 2005). In a review done by Tversky et al., (2002), many dynamic visualization cases do not benefit learning more than static visualization. Researches that discuss whether dynamic visualization helps students in understanding dynamic phenomena have yielded positive and negative results (Ainsworth, 1999; Schontz & Rasch, 2005). Other researchers claim that dynamic visualization brings the potentiality of misconceptions to a simple phenomenon (Schnotz & Rasch, 2005). Researches have shown that dynamic visualization does not show better learning achievement than static visualization (Tversky et al., 2002). According to Ayres & Paas (2007) one of the reasons why dynamic visualization is not so effective is because dynamic visualization is transient so that the students need to remember, select and integrate many things at the same time in processing information. Since students have a working memory with a limited capacity, dynamic visualization tends to create a high working memory load, hence will cramp learning. However, in a meta-analysis done by Hoffler & Leutner (2007) it is shown that in some researches dynamic visualization is more fruitful than static visualization, particularly when the instruction is about procedural knowledge.

The reason which is often given on the impossibility for dynamic visualization to be more effective than static pictures is that it does not give permanent information. It only gives transient information (Ainsworth & Van Labeke, 2004; Hegarty, 2004) which may force extraneous cognitive load (that is, cognitive load that is caused by the available instructional material format) which has to be reduced as much as possible (Ayres & Paas, 2007), because of the limitation of temporal working memory (van Merrienboer & Sweller, 2005).

An analysis that was done by Hoffler & Leutner (2007) showed the superiority of dynamic visualization over static visualization. In addition, Hoffler & Leutner (2007) found some moderating effects such as the role of animation (decorational vs representasional) and level of realism. Other moderating impacts of dynamic and non-dynamic visualizations include, for example, cognitive style (Hoffler, 2010), prior knowledge (Kalyuga 2008), and spatial ability (Hays 1996).

To design good instruction, one needs to consider student ability and student characteristics. Reigeluth (1983), explicitly places student characteristic as dominant variable in an instructional design. Student characteristic consists of his or her learning experience that has an effect on the effectiveness of learning process (Seels & Richey, 1994). Student characteristic according to Degeng (2013) is an aspect or quality of individual student that he or she already has. Student characteristic that can be identified as the most influential factor in the process and achievement in learning consists of intelligence, prior ability, spatial ability, cognitive style, learning style, motivation, and sociocultural factors. Student ability consists of various types, including spatial ability. Spatial ability is related to instruction which uses visualization (Lee, 2007).

Spatial ability is a point that has to be considered when designing visualization in learning. Spatial ability has long been recognized as individual ability which is part of general intelligence. Spatial ability is crucial to be considered when learning from visualization, but even the more important is a good design that supports learning environment (Hoffler, 2010). Students who have low spatial ability can be reinforced by various modifications of visualization design (Hoffler, 2010). One of the issues in science instruction research is what instructional condition, and what knowledge dimension are correlated with student spatial ability and learning achievement (Wu & Shah, 2004).

Student characteristic needs to be considered in instruction with dynamic and static visualization (Höffler & Leutner, 2007). Student spatial ability has an important involvement in instruction with dynamic and static visualization (Höffler, 2010). Hegarty & Waller (2005) state that students differ in their internal visuospatial representation quality depending on whether they have high or low spatial ability. Studies in this domain have shown that students with higher spatial ability do better than those who have low spatial ability when they learn from visualization. As an example, Hegarty & Sims (1994) found that students with high spatial ability learn better than those with low spatial ability. Students with high spatial ability show better performance than those with low spatial ability. This main effect is conformable with Hoffler's finding (2010).

Researches on cognitive load show that individual difference can influence learning achievement (de Jong, 2010). The individual characteristic that interacts with the effect of cognitive load is spatial ability (de Jong, 2010). Some studies reported the effect of student spatial ability, for example, Mayer & Sims (1994) did a study in which students learned about the function of a bicycle tire pump. A group that saw animations simultaneously with narrations explaining about the mechanism of the pump and another group saw the animations before the narrations. The group that saw animations simultaneously with narrations did better than the one that saw animations before narrations. This effect was strong for the high spatial ability students and was not shown by those with low spatial ability. Another research reported the effect of cognitive load in connection with to spatial ability (Huk, 2006).

In general, instruction with dynamic and static visualization has a positive relation with spatial ability on learning achievement (Hoffler, 2010). Student's high spatial ability is very useful in instruction with dynamic and static visualization. This implies that high student spatial ability enables the student to understand an extract visual information better in learning with dynamic visualization, and, on the other hand, activate their minds better when learning than when they learn from static visualization.

In addition, the impact of spatial ability on learning from dynamic and static visualization was tested in a meta-analysis by Höffler (2010) in which researches that investigated the effect of spatial ability on static visualization, or dynamic visualization, or both, dynamic and static visualization. The result showed that spatial ability has a positive effect on instruction both with dynamic and static visualization. Then, according to the hypothesis that states that ability is a compensation, the average effect of spatial ability on instruction with static visualization was higher than that on instruction with dynamic visualization.

### *Problem of Research*

In the research we have studied a spatial ability as a factor that has to be considered in design of instruction visualization. Students' spatial ability plays an important role in instruction with dynamic and static visualizations. In detail, the research questions are: 1) whether there are any significant differences in learning achievement of the eight grade students between the group of students who learned from dynamic visualization and those who learned from static visualization?; 2) whether there are any significant differences in learning achievement between the eighth grade students between the group of students who have high spatial ability and those who have low

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spatial ability?; 3) whether there is an interaction between visualization type (dynamic visualization and static visualization) and spatial ability (high and low) on learning achievement of the eighth grade students?

*Research Focus*

The focuses of this research were as follows: 1) investigate the effect of visualization (dynamic visualization and static visualization) in learning achievement, and 2) investigate the effect of students spatial ablility (high and low) in learning achievement.

## Methodology of Research

*General Background of Research*

This research used 2x2 factorial quasi-experiment with non-equivalent control group design. Based on the procedure, the 2x2 factorial experiment design (Ary et al., 2010) used is as shown in table 1. With the factorial design such as this, the main effect and the interaction effect of all of the treatment variables can be determined.

**Table 1. Pattern of 2 x 2 factorial experiment.**

| | | Type of Visualization | |
|---|---|---|---|
| | | Dynamic | Static |
| Spatial Ability | High Spatial | Group 1 | Group 2 |
| | Low Spatial | Group 3 | Group 4 |

Table 1 shows that the types of visualization used in this research had two dimensions, i.e., dynamic and static visualization. Spatial ability also had two dimensions, i.e., high and low spatial ability. Thus, the main effect and the effect of interaction between treatment variables can respectively be found and sorted into two groups.

The main effects, i.e., 1) the effect of the variables of the types of visualization and 2) the effect of spatial ability variables. In the first main effect, the effect of dynamic and static visualization would be found without looking at the effect of spatial ability. While for the second main effect, the effect of high and low spatial ability would be found without looking at the effect of the variables of the types of visualization (dynamic and static visualization) and spatial ability (high and low). The effect of the interaction of the treatment variables consisted of 1) the effect of dynamic and static visualization on the group of students with high and low spatial ability and 2) the effect of high and low spatial abilities on the group with dynamic and static treatment.

*Sample of Research*

The sample consisted of the students of Sekolah Menegah Pertama Negeri 1 Singaraja, Indonesia (State Junior High School 1 Singaraja, Indonesia) and the students of Sekolah Menegah Pertama Negeri 4 Singaraja, Indonesia (State Junior High School 4 Singaraja, Indonesia) with two classes from each school. The sample consisted of 115 eighth grade students (53 boys and 62 girls) State Junior High School in Singaraja, Indonesia. More specifically, 65 of them had high spatial ability and 50 students had low spatial ability.

*Instrument and Procedures*

This research used two types of instrument, i.e, 1) an instrument for conducting the treatment intervention and 2) an instrument for measuring prior knowledge (pre-test) and intervention result (post-test). The first type of instrument was in the form of dynamic and static visualizations, the process of development of which is reported in another section in this report, that is, in the subheading dynamic and static visualization development. While the second type of instrument was an instrument to measure the dependent variables as the direct effect of the treatments. The results obtained (through the post-test) would be used as a research analysis unit. The instrument consisted of a learning achievement test. The pre-test functioned as the initial test to collect prior knowledge which was positioned as covariate variable.

The procedure for developing the two types of test was as follows: 1) identifying basic competencies, 2) identifying learning achievement indicator, 3) formulating learning objective, 4) designing test items based on learning achievement, 5) writing the planned test items in a test matrix, 6) writing test items, 7) writing research rubric, 8) expert judgement, 9) field test,10) analyzing the result of the field test, 11) test item revision, and 12) finalizing the writing of the instruments. The learning achievement test functioned to measure the students' learning achievement on transportation system of organisms and human excretion system. The learning achievement test was designed in the form of multiple choice test and essay test. The learning achievement test for the pre-test was the same as the post-test, only the item number and the placement of options were different.

The learning achievement test developed consisted of 52 multiple choice items. The learning achievement test was a multiple-choice test with four options, in which if the students answered correctly they would get one score and if the answer was not correct they would get zero. The result of tryout showed that the number of items which met the level of difficulty and discrimination index was forty with the Alpha Cronbach of the learning achievement for multiple choice of .78.

Spatial ability was measured using paper Folding Test (Ekstrom, French, Harman, & Dermen, 1976). This spatial ability test has been used broadly to measure visualization spatial ability. The result of computation showed that all of the items in paper folding test could be used in the research with the reliability of .82.

The procedure of the experiment was specified as follows: 1) before the treatment was given to all of the subjects, they were given a spatial ability test and pre-test, 2) after the subjects finished doing the test, the treatment started in the class. Each of the students' computers had been installed with dynamic and static visualization instructions, and 3) after being given the treatment, the subjects were given a post-test.

### *Data Analysis*

The data were collected and analyzed using the statistical analysis of covariance (ANCOVA). ANCOVA was used to test the three-research hypothesis. The pre-test was used as covariate. Before doing the hypothesis testing, variance homogeneity test and data linearity test were done. The normality testing was done using Kolmogorov-Smirnov statistical test and Shapiro-Wilk test while homogeneity test was done using Levene's test method. All of the test used 5% level of significance ($\alpha = .05$). All statistical analyses were done by using SPSS 21 for Windows software.

## Results of Research

The number of students involved in the sample were 115 students. The distribution of the sample based on treatment group and spatial ability is presented in Table 2.

**Table 2. Distribution of sample of research based on type of visualization and spatial ability.**

| | Visualization | | Number |
|---|---|---|---|
| | Dynamic | Static | |
| High Spatial | 31 | 34 | 65 |
| Low Spatial | 24 | 26 | 50 |
| Number | 55 | 60 | 115 |

Table 2 shows that the distribution of sample was even enough in each group of treatment. The number has met the criterion recommended for 2x2 factorial analysis, that is, each cell minimally has a sample of 20 (Hair, et al., 2006).

The description of the condition of the variable of learning achievement in each group of treatment is presented in Table 3.

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**Table 3. Statistical description of the post-test.**

| Visualization | Spatial Ability | Mean | Std. Deviation | N |
|---|---|---|---|---|
| Dynamic | High | 84.52 | 5.86 | 31 |
| | Low | 75.39 | 6.83 | 24 |
| | Total | 80.54 | 7.73 | 55 |
| Static | High | 73.00 | 5.58 | 34 |
| | Low | 70.68 | 6.19 | 26 |
| | Total | 72.00 | 5.91 | 60 |

The result shows that the means in learning achievement in types of visualization (dynamic and static visualization) and levels of spatial ability (high and low) differ. It is shown in Table 2 that learning achievement of the students who learned from dynamic visualization (M = 80.54; SD = 7.73) was higher than the instruction using static visualization (M = 72.00; SD = 5.91). The learning achievement of the students who learned from dynamic visualization was higher than that of those who learned from static visualization.

It is shown in Table 3 above that learning achievement of the students with high spatial ability in the instruction using dynamic visualization (M = 84.52; SD = 5.86) was higher compared to that of the students who had low spatial ability (M = 75.39; SD = 6.83). The learning achievement of the high spatial ability students in instructions using dynamic visualization was higher than that of those who had low spatial ability.

It is shown in Table 3 above that the learning achievement of the students with high spatial ability in instruction using static visualization (M = 73.00; SD = 5.58) was higher than that of the students with low spatial ability (M = 70.68; SD = 6.19). The learning achievement of the students with high spatial ability in instruction using static visualization was higher than that of the students with low spatial ability.

Before doing hypothesis, testing using 2x2 factorial analysis of covariance (ANCOVA), a test was done to know whether there was a correlation between the Pre-test and the post-test. To determine covariate, Pearson Correlation Test was done. The result of Pearson Correlation Test is shown in Table 4.

**Table 4. Result of Pearson correlation test.**

| | | Pre-test | Post-test |
|---|---|---|---|
| Pre-test | Pearson Correlation | 1 | .378 |
| | Sig. (2-tailed) | | .039 |
| | N | 115 | 115 |
| Post-test | Pearson Correlation | .378 | 1 |
| | Sig. (2-tailed) | .039 | |
| | N | 115 | 115 |

The result of analysis showed that the pre-test score had a significant correlation with post-test score after the instruction that used visualization was given ($r = .378$; $p < .05$). The correlation showed the pre-test as covariate. Based on this the hypothesis test used was analysis of covariance (ANCOVA).

The 2x2 factorial ANCOVA test was done by using SPSS 21 for Windows at by 5% level of significance. The use of ANCOVA based on the result of requirement analysis test had met the requirement. The result of ANCOVA test was explained based on the result of Test of Between Subject Effects to see whether there was a difference in dependent variable individually in the treatment group. The test of the effect between variables to test the null hypothesis, the Test of Between-Subjects Effects was used. The result is shown in Table 5.

**Table 5. Result of tests of between-subjects effects.**

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Corrected Model | 3340.172a | 4 | 835.043 | 22.651 | .0001 |
| Intercept | 5352.808 | 1 | 5352.808 | 145.200 | .0001 |
| Pre-test | 38.639 | 1 | 38.639 | 1.048 | .0001 |
| Visualization | 1453.570 | 1 | 1453.570 | 39.429 | .0001 |
| Spatial ability | 901.741 | 1 | 901.741 | 24.461 | .0001 |
| Visualization * Spatial ability l | 360.880 | 1 | 360.880 | 9.789 | .308 |
| Errors | 4055.166 | 110 | 36.865 | | |
| Total | 673160.773 | 115 | | | |
| Corrected Total | 7395.338 | 114 | | | |

The result of analysis indicated that there was a significant difference in learning achievement viewed from the type of visualization (dynamic and static visualization) ($F = 39.42$; $p < .05$). The same result was also found in learning achievement of the students with high spatial ability and low spatial ability. The result of analysis indicated that there was a significant difference in learning achievement viewed from spatial ability (high and low) ($F = 24.46$; $p < .05$).

The result of the third hypothesis testing showed that there was the effect of interaction between visualization (dynamic and static visualization) and spatial ability (high and low). The result of the Test of Between-Subjects Effects presented in Table 5 showed that there was no interaction ($p > .05$).

## Discussion

### *Effect of Visualization (Dynamic and Static Visualization) on Learning Achievement*

To understand how visualization can be used effectively in instruction, the type of visualization is an important parameter and needs to be considered in research. This research was related to the impact of visualization types used in science instruction at eighth grade and the interaction between the types of visualization and student spatial ability.

The result of research showed that the use of dynamic visualization was more powerful than the use of static visualization in instruction on transportation system in organisms and human excretion system. This research finding is in line with the findings of previous studies (Ali & Ambusaidi, 2017; Barak & Dori, 2011; Hoffler & Leutner, 2007; Lin & Dwyer, 2010; Schnotz & Rasch, 2005; Schnotz & Lowe, 2008; Wu, Lin, & Hsu, 2013). The superiority of dynamic visualization to static visualization indicates that dynamic visualization helps students to build a deep understanding (Kühl, Scheiter, Gerjets, & Edelmann, 2011).

The use of dynamic visualization to show changes directly makes it possible for memory to proceed in students' cognitive process more easily (Schnotz & Rasch, 2005). Mayer's cognitive theory (2001) states that knowledge is presented and manipulated through two cognitive channels, i.e., visual-pictorial and audio channels. Now instruction with visualization can facilitate cognitive processing and thus it can help students to get a deeper comprehending of the material (Kuhl et al., 2011). Dynamic visualization can facilitate student active involvement (Wichmann & Timpe, 2015). Dynamic visualization is an important instrument to present observable scientific process (Hegarty, 2004). At the time extraneous cognitive load is reduced, by adding visualization to the text, the students can invest their memory resource in the schemata. In the context of

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cognitive theory this process refers to germane cognitive load investment. The principle of multimedia can be explained by the reduction in extraneous cognitive load and the growth in germane cognitive load at the time of adding visualization to the text (Kühl, Scheiter, Gerjets, & Gemballa, 2011). The benefit of dynamic visualization is that students can directly describe spatial and temporal information changes (Schnotz & Lowe, 2008). These dynamic features, such as changes in the speed of an object, are the inherent properties of dynamic visualization which can directly be read, thus it reduces processing demand (Scaife & Rogers, 1996).

Dynamic visualization has a potentiality to describe directly speed, acceleration, etc. reversely proportionate to static visualization in which the dynamic quality of the instructional material has to be concluded by the students. Students with high ability will process dynamic features actively so that they can build a mental model (Mayer, Hegarty, Mayer, & Campbell, 2005). This is one of the potentialities of a transient quality (Betrancourt, 2005), since the motion is shown repeatedly, it makes it possible for the students to see it many times.

Static visualization does not provide visual movement information explicitly. With a rapid multimedia presentation, it may not give enough time to the students process mental animation which can be easily done based on a verbal narration interpretation of a careful static picture. In line with this result, Hegarty et al. (2003) found that an understanding of mechanic system was supported by animations and a series of three static diagrams that represented system phases, both support the understanding more effectively than the use of a static picture. An arrow button can show movements. In addition, the arrow can show a causal mechanism. Tversky et al., (2002) showed that the arrow in diagram which displayed a mechanical system was often interpreted as indication of functional causal and asymmetrical relation. Thus, an arrow might have caused the students to think of causal relation in the study. Finally, an arrow might function as a visual sign which led students' attention to the relevant parts in the display, preventing an unnecessary search (de Koning, Tabbers, Rikers, & Paas, 2007).

Dynamic visualization is continuous, so that it reduces its transience by providing an access for the students to the relevant information in its repeated cycle (Kühl, Scheiter, Gerjets, & Edelmann, 2011; Kühl, Scheiter, Gerjets, & Gemballa, 2011). In addition, dynamic visualization is different from static visualization. Dynamic visualization cannot only display spatial visual changes continually, but also has properties to directly display temporary information: for example, dynamic visualization makes it possible to display how much time is needed by an object to change its position from point A to point B, and whether this change is constant (Lowe, 2003; Schnotz & Lowe, 2008). In addition, dynamic visualization can exclusively show dynamic features, such as changes and speed.

According to Ali & Ambusaidi (2017), dynamic visualization helps in conceptualizing abstract concepts which may be difficult to understand by the students. Dynamic visualization can display observable scientific process (Wichmann & Timpe, 2015). Dynamic visualization makes it easy for the students to be actively involved through the control by the students such as: the students can start, stop, and this play again the information needed (Wichmann & Timpe, 2015). Thus, the result of the research is in accordance with the findings of previous researches.

The use of dynamic visualization to show changes directly makes the work of the memory in cognitive process in the student easier (Schnotz & Rasch, 2005). One of the potentialities of dynamic visualization lies in its transient characteristic (Betrancourt, 2005), since movements are displayed repeatedly so that the same information can be seen by the students over and over.

Visualization added to the text gives a concrete context for understanding words. This is the proof for the principle of multimedia: people learn better from words and pictures than from words only (Mayer, 2009). The students can perform better if they learn from printed texts and illustrations than from printed texts only (Mayer, Bove, Bryman, Mars, & Tapangco, 1996; Moreno & Valdez, 2005) or from narrations and animations than from narrations only (Mayer & Anderson, 1992; Moreno & Mayer, 1999; Moreno & Mayer, 2002).

Dynamic visualization can give a contribution to the ability to understand learning material in two ways. First, it makes it possible to represent concepts, phenomena, and process mentally. Secondly, it can be used to display challenging cognitive processes such as abstraction, imagination or creativity. A researcher who uses animation in teaching found that the more instruments used, the better the learning process will be (Najjar, 1998). Another study showed that the use of animation and visualization contributed to the student learning achievement (Barak & Dori, 2005, Dori et al 2003; Dori & Belcher, 2005), spatial ability and motivation to study (Barak, et al., 2011). Therefore, the finding of this research is in line with the former findings.

*Effect of Spatial Ability (High and Low) on Learning Achievement*

In this research, spatial ability refers to knowledge about location, movement, and spatial relation among objects in computerization model. The result showed that high students spatial ability in the group using dynamic and static visualization presentation was higher than that of the students with low spatial ability on transportation system in organism and human excretion. The finding is in line with the findings in (Hoffler, 2010; Huk, 2006; Mayer & Sims, 1994), in which spatial ability analysis showed that high spatial ability students in the dynamic group could develop knowledge better of an object in the type of visualization presentation while low spatial ability students did not have cognitive resources to form relations with the type of visualization presentation. Students who have high spatial ability got benefits from learning from dynamic visualization while those with low spatial ability could not (Huk, 2006; Mayer & Sims, 1994). Low students' spatial ability may not support dynamic visualization instruction, students who have low spatial ability build a mental model which is adequate for external represented text (Hays, 1996).

Hegarty & Waller (2005) stated that students differed in their internal visuospatial representation quality depending on whether they had high or low spatial ability. Studies related to this have shown that students with higher spatial ability outperformed those with low spatial ability in learning through visualization. Hegarty & Sims (1994) found that students with high spatial ability outperformed those with low spatial ability.

Generally, instruction with dynamic and static visualization has positive relation with spatial ability on learning achievement (Hegarty & Kriz, 2007; Hoffler, 2010). High students' spatial ability is very useful in instruction with dynamic and static visualization. This implies that high spatial ability makes it possible for the students to understand and extract visual information in learning with dynamic visualization, and on the other hand, activate the students' minds better than when they learn from static visualization (Hegarty & Kriz, 2007).

In addition, the effect of spatial ability on learning with dynamic visualization or static visualization was tested by meta-analysis by Höffler (2010). The result showed that spatial ability has a positive effect on instruction both with dynamic and static visualization. Then, based on the hypothesis which states that ability is a compensation, the multitude of the average effect for spatial ability in instruction with static visualization is higher than that in instruction with dynamic visualization. High spatial ability correlate with better learning achievement, the indication for the high spatial ability gives a benefit in dynamic visualization rather than static visualization. (Hoffler, 2010).

In line with the previous studies in chemistry education, spatial ability is a factor that influences students in solving problems (Wu & Shah, 2004). Students' spatial ability can influence how they see and settle a problem (Bodner & McMillen, 1986; Carter et al., 1987).

Students with high ability will actively process dynamic features so that they can build a mental model (Mayer, Hegarty, Mayer, & Campbell, 2005). The same result was obtained by Schnotz & Rasch (2005), in which students having low prior knowledge need more time to learn from static visualization than from dynamic visualization. The reverse is true for students with high prior knowledge.

Students having high prior knowledge tend to have a better cognitive ability to combine verbal and visual representation, on the other hand, students with low spatial ability have to use their cognitive ability fully to integrate verbal and visual representation (Lee, 2007). This can mean that high spatial ability makes it possible for the students to know more and to extract visual information in learning from dynamic visualization. Thus, this research is in line with previous findings.

*Interaction of Visualization (Dynamic and Static Visualization) and Spatial Ability (High and Low) on Learning Achievement*

The main effect from this research was that visualization presentation (dynamic and static visualization) shows that spatial ability did not show an interaction with learning achievement in understanding in the eighth-grade students. The ground for this result may be related to the characteristics of the knowledge and the characteristics of the visualization presentation. Understanding covers the structure and function of transportation system in organisms and human exertion system that can be represented effectively with words, pictures, and animations, while scientific principles and concepts behind the movement in transportation in organism and human exertion system may not be easily understood only by looking at representations with

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visualization (Wu & Shah, 2004). Also, worksheets were given to guide teaching and learning process, support from teachers, friends and technology may be needed by the students to develop a better understanding about transportation system in organism and human exertion system (Ainsworth, 2006; Goldman, 2003).

The type of visualization and students' spatial ability seem to be the determining factors in the effectiveness of an instruction. Anglin, et al., (2004) state that the effectiveness of the use of the pictures in instruction depends on how the pictures are applied and the characteristics of the lesson. The visualization which is characterized as the giving of illustrations in the form of real phenomena or as the strengthening of an explanation in the text contributes less in helping the students understand scientific concepts behind the phenomena. Similarly, simple conceptual visualization may not be needed for formal operational thinking maturity. Studies by Park & Lim (2008), and Rasch & Schnotz (2009) showed that there was a contribution from the mismatch between type of visualization and students' thinking maturity level. Spatial ability has an important role when students learn from visualization, since the students often need formation, retention, and internal representation manipulation.

## Conclusions

Based on the result and discussion, some conclusions can be made as follows 1) learning achievement of the students who learned from dynamic visualization and that of those who learned from static visualization had a significant difference. The significant difference shows that instruction with dynamic visualization has a better impact on learning achievement than the instruction with static visualization; 2) learning achievement of the students having high spatial ability was significantly different from that of those with low spatial ability. The significant difference shows that high spatial ability has a better effect on learning achievement than low spatial ability; and 3) type visualization (dynamic and static visualization) and spatial ability (high and low) showed no interaction on learning achievement.

There are many things that have to be followed up in this research. Some suggestions related to further studies are as follows 1) the result of the research showed different types of visualization and different levels of the students' spatial ability can influence learning achievement in science. Researchers, teachers, and instructional designers need to think that types of visualization can influence students' learning achievement. A combination of types of visualization and different sequences of presentation and their relation to individual characteristics can be explored further in further studies, 2) since spatial ability has an effect on instruction with visualization, further studies have to focus on how to design instructional formats that encourage students with low spatial ability, and 3) how to involve learners with low spatial ability in helping them processing information and making relations between representations. It becomes an important issue in science instruction. Science instruction and instructional material have to consider conceptual ability and spatial ability to support student's understanding through visualization presentation.

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