SketchUp-aided generative learning in solid geometry: Does it affected students’ spatial abilities?

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Abstract. Spatial ability is one of the abilities that should be mastered by students because daily human life requires it. Learning geometry that does not match the characteristics of students causes low spatial abilities. The purpose of this study was to determine the achievement and improvement of students' spatial abilities after they participated in SketchUp-aided generative learning. This research is quasi-experimental research to compare students who were receiving SketchUp-aided generative learning and direct learning. The research instrument was a test of spatial ability, and the subjects were students of class XII high school. The results showed that spatial ability increased after receiving SketchUp-Aided generative learning. The results of this study contribute to providing suggestions for teachers to apply SketchUp-aided generative learning.

1. Introduction
Mathematics is one of the sciences that humans often use in their daily activities so that mathematics is a human activity [1]. When constructing a building, the technician should have an insight into the geometry. Buying and selling that occurs in shopping centres require various operations, quantities and units. A child who is playing requires mathematics so that they can win fairly.

Geometry is a branch of mathematics that students should master in order to increase their sensitivity about time and space. There is geometry material that students should study for every level of primary and secondary school. For some students, geometry can make it easier for students to represent certain symbols and concepts in mathematics to make them look more real. However, for some other students, geometry provides more obstacles because it requires visualization with a particular point of view.

Spatial ability is one of the abilities that students should achieve after studying geometry. Regarding the science of the brain, the right brain provides a role to work concerning spatial abilities. Spatial abilities relate to creative object manipulation. To live their lives, students require spatial abilities so that they can develop their creative and imaginative powers through visualizing real objects in their minds. For students who have high spatial abilities, they know their location in a place and are not easily lost. Someone often who will be working in a workplace answers spatial ability tests. Besides, it helps students to expand their perspective globally on a particular object or problem. The concept of multiple intelligence categorizes this spatial ability into a different ability that is parallel to other abilities that support success [2].

Students can experience obstacles in learning and working if they do not practice their spatial skills. The low spatial ability of students causes them to experience difficulty in learning geometry [3].
Those who have low spatial abilities can have difficulty determining direction if they move from one place to another. Also, they can have poor navigation control because they have difficulty predicting the location of an object. When studying mathematics, they can learn more slowly than others because mathematics is abstract. To get students to think abstractly, students must first go through concrete thinking stages. However, as previously mentioned, students sometimes experience difficulties when they concretize abstract objects. It becomes a complicated thing to understand because student characteristics result in different ease of processing. The aspects of low spatial ability are 1) sketching three-dimensional objects in two-dimensional images, 2) identifying spatial images as flat objects that are parallel, 3) finding visual representations in the paper, thoughts, and technological tools, and 4) changing three-dimensional objects into two dimensions which are seen from different points of view without sufficient support [4].

Students' spatial abilities can support their cognitive abilities to develop better and improve other mathematical abilities. If students have high spatial abilities, then they have high retention so that if they need it and will find it easier when they recall the information required to learn mathematics [5]. Spatial abilities have proven to be very useful in the fields of science, engineering, technology, and mathematics and 45% of doctors, 30% masters, and 25% of undergraduates have level 9 spatial skills [6].

Researchers in the field of mathematics have used a variety of ways to improve students' spatial abilities. The multimedia course lab module can improve the abilities of high school students [7]. Learning drawing techniques effectively improves the spatial abilities of high school students [8]. MOODLE-based multimedia mathematics learning can improve spatial abilities [9]. Students who have high spatial abilities can significantly undergo the mathematics learning process more efficient [10].

![Image of spatial orientation](image)

**Figure 1. The Example of a spatial orientation**

Spatial ability is the ability to understand visual images accurately, build mental and imaginary representations of visual information, understand and manipulate relationships between objects [11]. Its components consist of spatial visualization symbolized by Vz, spatial orientation symbolized by SO, spatial relations or speeded rotation symbolized by SR, closure speed symbolized by CS, the flexibility of closure, field independence or disembedding symbolized by CF, the perceptual speed which is symbolized by P, spatiotemporal ability or dynamic spatial ability symbolized by DSA, and environmental ability symbolized by EA [12].

The definition of them is as explained below.

1) Spatial visualization is the ability to imagine the manipulation, rotation, rotation, reversal of an object without reference.
2) Spatial orientation is the ability to imagine the appearance of an object from different perspectives.
3) Spatial relations is the ability to identify identical objects if the object is rotated or mirrored.
4) Closure speed is the ability to access spatial representations in long-term memory when incomplete or unclear clues to those representations are displayed.
5) The flexibility of closure is the ability to find hidden shapes in a larger form.
6) Perceptual speed is the ability to find configurations in a confusing or chaotic material.
7) Spatiotemporal ability is the ability to make decisions related to moving objects.
8) Environmental ability is the ability to integrate information related to natural or artificial objects in the environment.

Figure 1 and Figure 2, respectively show an example of the spatial orientation and visualization test [13].

Researchers need to explore the spatial ability to find the suitability of learning geometry so that it can improve. This study aims to determine the achievement and enhancement of students' spatial abilities who receive SketchUp-Aided Generative Learning (SAGL) and Direct Learning (DL). Besides, the purpose of this study was to determine the effect of SAGL and DL on spatial abilities.

2. Method
This research includes quantitative research to determine the comparison between the dependent variables which are influenced by the independent variables. The researcher gave treatment to groups of students, and these groups consist of an experimental class and a control class. The experimental class received SAGL, while the control class received DL. This study involved students' Prior Mathematical Knowledge (PMK) consisting of students with high level, students with moderate level, and low level. The sample of this study were students of grade XII majoring in mathematics and natural sciences high school for the 2018/2019 academic year, totalling 219 students. They come from four schools consisting of a public school in Sokaraja and three public high schools in Purwokerto, Central Java, Indonesia. The spatial ability test is applied to determine the level of students' spatial ability which is carried out before and after the learning treatment is given to students. The spatial abilities tested in this study are included in the visualization and orientation categories. The form of questions from this spatial ability test is in the form of a description because students' thinking abilities that are not just guessing results want to be known. Data processing performed in this study was a descriptive statistic and Mann-Whitney test.

3. Result and Discussion
Based on Table 1, the achievement of spatial ability based on learning does not differ. Even though the spatial ability achievement average of students who received SAGL was more than the spatial ability achievement average of students who received DL, the difference was only 58.99 - 56.11 = 2.88. Table 1 can further show that with an ideal maximum score of 100, the difference score between the values of 58.99 and 56.11 is small. Likewise, the standard deviation of spatial ability achievement
between students who received SAGL and students who received DL had a tiny difference, was only 0.03. It shows that the distribution of data on the achievement of spatial ability based on learning is almost the same.

### Table 1. The summary of spatial ability achievement

| Instruction | N  | Minimum Score | Maximum Score | Mean  | Standard Deviation |
|-------------|----|---------------|---------------|-------|--------------------|
| SAGL        | 113| 0.00          | 98.15         | 58.99 | 22.88              |
| DL          | 106| 0.00          | 99.07         | 56.11 | 22.85              |

The calculation result of the Mann-Whitney test in Table 2 shows a significance value of 0.298. This value is a 2-tailed significance value, so to get a 1-tailed significance value, this value is divided by two so that the 1-tailed significance value is 0.149. This value is more than 0.05 then H0 is accepted. Thus, the conclusion is that with a confidence level of 95%, the median spatial ability achievement of students who received SketchUp-aided generative learning is the same as the median spatial ability achievement of students who received DL.

### Table 2. Mann-Whitney test results of spatial ability achievement

| Instruction | N  | Significance | Decision   |
|-------------|----|--------------|------------|
| SAGL        | 113| 0.149        | Accept H0  |
| DL          | 106|              |            |

Table 3 shows that for students with the high and moderate level in prior mathematical knowledge, the average spatial ability achievement of students who received SAGL was higher than the spatial ability achievement of students who received DL, namely 68.52 > 63.64 for students with high level and 64.78 > 54.99 for students with the moderate level. It means that the difference in achievement is 4.88 and 9.79, respectively. For students with low level, the spatial ability achievement average of students who received SAGL was lower than that of students who received DL, namely 44.40 < 49.34 so that the difference was 4.94. Apart from that, the difference between the standard deviations was not too much different, namely only 1.80; 4.05; and 3.38 for students with high, medium, and low level. It means difference achievement of spatial ability based on prior mathematical knowledge is not different.

### Table 3. The summary of spatial ability achievement based on prior mathematical knowledge

| Instruction | PMK Level | N  | Minimum Score | Maximum Score | Mean  | Standard Deviation |
|-------------|-----------|----|---------------|---------------|-------|--------------------|
| SAGL        | High      | 43 | 21.30         | 98.15         | 68.52 | 21.34              |
| DL          | High      | 34 | 15.74         | 97.22         | 63.64 | 19.54              |
| SAGL        | Moderate  | 30 | 26.85         | 98.15         | 64.78 | 20.35              |
| DL          | Moderate  | 41 | 0.00          | 99.07         | 54.99 | 24.40              |
| SAGL        | Low       | 40 | 9.26          | 90.74         | 49.34 | 22.38              |
| DL          | Low       | 31 | 9.26          | 90.74         | 49.34 | 22.38              |

Based on Table 4, the enhancement in spatial ability between students who get SAGL and students who get DL seems to have a difference. The average enhancement in the spatial ability of students who received SAGL was greater than the average enhancement in the spatial ability of students who received DL with a difference of 0.279 - 0.132 = 0.147. Even though the maximum value of enhancement in the spatial ability of students who received DL was more than the enhancement in the spatial ability of students who received SAGL, the difference was small, namely only 0.957 - 0.915 = 0.042. Besides, the minimum score for enhancement in spatial ability students who received SAGL was far above that of students who received DL. The difference is –0.770 – (–0.333) = 0.437. It causes the range of enhancement in spatial ability students who get DL is greater than the enhancement in spatial ability of students who get SAGL, so the standard deviation is also greater. So, the
enhancement in spatial ability of students who received SAGL was better than the enhancement in spatial ability students who get DL.

**Table 4. The summary of spatial ability enhancement**

| Instruction | N   | Minimum Score | Maximum Score | Mean   | Standard Deviation |
|-------------|-----|---------------|---------------|--------|--------------------|
| SAGL        | 113 | -0.333        | 0.915         | 0.279  | 0.268              |
| DL          | 106 | -0.770        | 0.957         | 0.132  | 0.341              |

Based on the results of the calculation of the Mann-Whitney test in Table 5, the 2-tailed significance value obtained is 0.001 so that the 1-tailed significance value is 0.001 divided by two, which is equal to 0.0005. This value is less than 0.05. Thus, $H_0$, which states that the median enhancement in spatial ability of students who get SAGL is the same as the median enhancement in spatial ability of students who get DL was rejected. So, the conclusion is that with a confidence level of 95%, the median enhancement in spatial ability of students who received SAGL was more than the median enhancement in spatial ability of students who received DL.

**Table 5. Mann-Whitney test results of spatial ability enhancement**

| Instruction | N   | Significance | Decision |
|-------------|-----|--------------|----------|
| SAGL        | 113 | 0.001        | Reject $H_0$ |
| DL          | 106 |              |          |

Table 6 shows that the most significant difference in the average increase in spatial ability occurred between students who received SAGL with high level in prior mathematical knowledge and students who received DL with high level, which was $0.257 - 0.058 = 0.199$. For students with moderate level, the difference in the increase in spatial ability between students who get spatial ability and students who get DL is $0.370 - 0.197 = 0.173$. The smallest difference in the average increase in spatial ability occurred between students who received SAGL with low level and students who received DL with low level, which was $0.232 - 0.129 = 0.103$. It means that the increase in spatial ability students who get SAGL is always more significant than the increase in students who get DL for each level of prior mathematical knowledge. Meanwhile, the largest standard deviation occurred in the increase in spatial ability students who received DL with moderate level, which was 0.383 and the smallest standard deviation occurred in the increase in spatial ability students who received SAGL with low level, which was 0.190.

**Table 6. The summary of spatial ability enhancement based on prior mathematical knowledge**

| Instruction | PMK Level | N   | Minimum Score | Maximum Score | Mean   | Standard Deviation |
|-------------|-----------|-----|---------------|---------------|--------|--------------------|
| SAGL        | High      | 43  | -0.333        | 0.915         | 0.257  | 0.300              |
| DL          |           | 34  | -0.667        | 0.739         | 0.058  | 0.322              |
| SAGL        | Moderate  | 30  | -0.305        | 0.913         | 0.370  | 0.295              |
| DL          |           | 41  | -0.770        | 0.957         | 0.197  | 0.383              |
| SAGL        | Low       | 40  | -0.162        | 0.699         | 0.232  | 0.190              |
| DL          |           | 31  | -0.500        | 0.707         | 0.129  | 0.293              |

The results of the research related to spatial abilities indicate that overall the achievement of students’ spatial ability who got SAGL was the same as the achievement of students who received DL. Even so, the increase in spatial ability students who received SAGL was more than the increase in spatial ability students who received DL. It is in line with the results of research, which states that students’ spatial abilities appear to have developed after using SketchUp [14, 15]. Both of them stated that the comparison of the achievement of the ability to visualize spatial shapes shows that activities assisted by SketchUp are more effective than activities that involve concrete models of traditional shapes and tools.
4. Conclusion
The results of the research show that the spatial ability achievement of students who received SAGL and DL is moderate, and SAGL can enhance the students’ spatial ability. Regarding the achievement of spatial abilities, the achievement of spatial ability for students who received SAGL is no better than the achievement of spatial ability for students who received DL. Regarding the improvement of spatial abilities, the enhancement of spatial ability for students who received SAGL is better than the enhancement of spatial ability for students who received DL.

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