Implementation of Mathematics Learning-Assisted Cabri 3D Software to Improve Spatial Ability of High School Students on Three Dimensional Geometry

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Abstract. The purpose of this study to analyze student’s spatial abilities to resolve 3D geometry problems through mathematics learning-assisted using Cabri 3D software. The population in this study were students from one of High School Student in Kuningan, West Java. Selection of sample by purposed random sampling, the experimental class is taught mathematics learning-assisted using Cabri 3D, while the control class is taught by conventional learning. This study was quasi-experimental with pretest and posttest control group design. Data analysis using two way anova by linking between learning model with gender factor and early mathematical abilities (KAM). Based on the results; (1) The enhancement of student’s spatial abilities through Cabri 3D was higher than the conventional learning; (2) based on gender, there were no significant effect of student’s spatial abilities who exposed with Cabri 3D and conventional learning; (3) based on KAM, there was significant effect of student’s spatial abilities among ability of high, middle, and low KAM. The differences occur between high, middle and low KAM. (4) based on the questionnaire results, students’ responses to the positive Cabri 3D positive model, as much as 73.85% agree that learning Cabri 3D can improve understanding, interest and students’ abilities to learn the concept of 3 dimensional geometry. Based on this result, mathematics learning-assisted Cabri 3D can be applied in the process of mathematics learning in high School.

Keywords: Cabri 3D, Spatial Ability, Geometry Concept, Three Dimensional Geometry

1. Introduction

Background
Mathematics is a branch of science that has contributed significantly to the development of technology and human civilization, many applications of mathematical concepts that become the foundation of scientific and technological development today. One of the studies in mathematics learning in schools is geometry, the basic concept of geometry is needed in the application of other branches of science such as: physics, engineering, architecture and others, but in reality on the ground, geometry is not a subject that is quite liked, in studying geometry, especially with regard to drawing, manipulating and constructing conjectures to solve 3-dimensional geometry problems. Based on the results of the research, it is found in the field that students have difficulty understanding the concept of geometry, especially
the material that involves good spatial ability of the students, in space geometry, it seems to be much harder for them to be certain of a visual noticing, and they may need new tools to study representations and to solve problems (Mithalal)[1]. The National Council of Teachers of Mathematics recommends "the mathematics curriculum for grade 5-8 should include the study of the geometry of one, two, and three dimensions in a variety of situations, so that students can visualize and represent geometric figures with special attention to developing spatial sense. In many countries the development of spatial ability is a major aim in many geometry guideline (Clements & Battista)[2]. However our geometry curricula in Indonesia do not provide enough opportunities for the development of spatial ability among student (Yuliardi)[3].

**Definition of Spatial Ability**

Spatial ability is one aspect of cognitive. Spatial abilities is one of the intelligences of eight multiple intelligences which Howard Gardner pointed out (Amstrong)[4]. In the literature, the concept of spatial ability is used for the abilities related to the use of space. Two major components of spatial ability have been identified: spatial relations and spatial visualization (Clements & Battista)[5]. Linn and Peterson (Bogue)[6], said spatial abilities (spatial ability) consists of rotation mental (mental rotation), spatial perception (perception spatial) and spatial visualization (visualization spatial). Maier divides spatial abilities into 5 indicators: (1) Spatial Relations means the ability to comprehend the spatial configuration of object or parts of an object and their relation to each other. (2) Mental Rotation involves the ability to rapidly and accurately rotate 2D or 3D figure (3) Spatial visualisation comprises the ability to visualise a configuration in which there is movement or displacement among (internal) parts of configuration. (4) Spatial Perception require the location of horizontal and vertical in spite distracting information. (5) Spatial Relation ability to comprehend the spatial configuration of object or part of an object and their relation to each other (Maier)[7]. The picture below shows a question to measure students' spatial early ability:

| Take a look at the picture below! | Take a look at the picture below! |
|----------------------------------|----------------------------------|
| ![Image](image1)                 | ![Image](image2)                 |
| If the image above opens into a net, which is the net below which is identical to the picture above. | If the image above is rotated, which image below is identical to the picture above. |

**Figure 1.** Examples of instruments to measure indicators of students' spatial abilities (Spatial – Reasoning)

**Figure 2.** Examples of instruments to measure indicators of students' spatial abilities (mental-rotation)
Cabri Geometry is a commercial interactive geometry software produced by the French company Cabrilog for teaching and learning geometry and trigonometry. It was designed with ease-of-use in mind. The program allows the user to animate geometric figures, proving a significant advantage over those drawn on a blackboard. Relationships between points on a geometric object may easily be demonstrated, which can be useful in the learning process. There are also graphing and display functions which allow exploration of the connections between geometry and algebra. The program can be run under Windows or the Mac OS. The Dynamic Geometry Software Cabri 3D for exploring three-dimensional geometry was launched in 2004. It promises to revolutionize computer assisted visualization and reasoning in 3D geometry. Three-dimensional objects such as prism, cylinder and cone can be constructed, rotated and seen from a certain aspect on the screen and also prisms can be opened on the screen. Prisms and half plane can be intersected and thus, new three-dimensional objects may be formed. These features offer incredible opportunities to the student to develop their spatial skills. Also, because some measurements such as angle, length and surface area may be obtained on the screen via this software, the students have the opportunities to learn three-dimensional geometry by explorations (Guven & Kosa)[8]. The following is an example of a problem to measure spatial abilities of students in three-dimension material.

Example 3D Geometry Concept Question :
1. Known cube ABCD.EFGH, with side length 6 cm. Distance point E to the BDG field is ...

Answer :
To help solve the above problem we use 3D cabri software to visualize the solution:
Distance point E to the BDG field is EQ

\[
PQ = \frac{PG^2 + EP^2 - EG^2}{2PG}
\]
\[
EP = \sqrt{EA^2 + AP^2}
\]
\[
EP = 3\sqrt{6}
\]
\[
PQ = \frac{(3\sqrt{6})^2 + (3\sqrt{6})^2 - (6\sqrt{2})^2}{2(3\sqrt{6})}
\]
\[
PQ = \sqrt{6}
\]
\[
EQ = \sqrt{EP^2 - PQ^2}
\]
\[
EQ = \sqrt{(3\sqrt{6})^2 - (\sqrt{6})^2}
\]
\[
EQ = 4\sqrt{3}
\]

2. Methodology
This study is an experimental research in quasi form (quasi experiment). Therefore, the sample subject is not a random choice. The sample subject is the learning group in their classes, so if the sample is random, it would be difficult and disrupt the teaching activity. This study engages spatial ability with gender (male and female) and student’s KAM factor (high, middle, and low). The research sample consisted of two homogeneous Form Four classes from one of High School Student in West Java, Indonesia. A total of 76 students involved. Experiment class is given with Mathematics Learning-Assisted Cabri 3D while control class with Conventional Learning (CL). The conducted research design is Pretest-Posttest Control Group Design (Ruseffendi) [9]. Briefly, the conducted research design can be defined as below:
O       X         O   (1)
O       O  (2)

Explanation :
X :  Mathematics Learning-Assisted Cabri 3D
O :  pretest = posttest mathematics spatial abilities

The selected experimental design is a factorial design that is categorized as $2 \times 2 \times 3$ factorial design. The design of this study was chosen because the independent variables were divided into three, i.e., mathematical learning using software (Model A) and without using software assistance (Model B). The moderator variables are also divided into two groups: gender based and students' early mathematical spatial abilities. The $2 \times 2 \times 3$ factorial design intended according to Issac and Michal [10] can be seen in the following table:

| Table 1. Factorial Design with engages mathematics learning model, gender and Early Mathematical-Spatial Abilities. |
|---|---|---|---|---|---|
| KAM Cabri 3D | Male | Female | Conventional Learning | Male | Female |
| High | 1MH | 1FH | 2MH | 2FH |
| Middle | 1MM | 1FM | 2MM | 2FM |
| Low | 1ML | 1FL | 2ML | 2FL |

3. Result and Discussion

Result

Analysis using SPPS version 20 used for: 1) Descriptive analysis (describing raw data), 2) Test requirements data analysis (test of normality and homogeneity), and 3) hypothesis test used Two way Anova (Sugiyono) [11]. The following table shows differentiation Test of the student’s understanding Enhancement both learning group.

| Table 2. Differentiation Test of the Student’s Spatial Ability Enhancement both Learning Group |
|---|---|---|---|---|---|
| Learning Group | n | Mean | t | Sig. (1-tailed) | Ho |
| Cabri 3D Learning | 39 | 0,657 | -2,33 | 0,044 | Rejected |
| Conventional Learning | 37 | 0,585 | | | |

Table 2 shows that the value of the probability or sig. (One-tailed) is smaller than $\alpha = 0.05$, so Ho rejected. Thus, students who earn Cabri 3D approach had an average of spatial ability is higher significantly than students who received Conventional Learning.

| Table 3. Two-way ANAVA on N-Gain Spatial Ability based on KAM & Gender |
|---|---|---|---|---|---|
| Source | Type III Sum of Squares | df | Mean Square | F | Sig. | Ho |
| Corrected Model | 1.048 | 5 | 0,210 | 11,287 | 0,000 | Rejected |
| Intercept | 27.023 | 1 | 27.023 | 1454,67 | 0,000 | Rejected |
| Gender | 0.014 | 1 | 0.014 | 0.765 | 0.385 | Accepted |
| KAM | 0.958 | 2 | 0.479 | 25.782 | 0.000 | Rejected |
| Gender * KAM | 0.007 | 2 | 0.004 | 0.197 | 0.821 | Accepted |
Based on the results in Table 3 we can conclude:

3.1.1 Corrected Model:
Influence All independent variables (Gender, KAM and Gender interaction with KAM or "Gender * KAM") collectively against the dependent variable (Exam Score). If Significance (Sig.) <0.05 (Alfa) = Significant. An example above 0,000 means a valid model.

3.1.2 Intercept:
The value of the dependent variable changes without the need to be influenced by the existence of independent variables, meaning that without the influence of independent variables, the dependent variable can change its value. If Significance (Sig.) <0.05 (Alfa) = Significant. An example above 0,000 means a significant intercept.

3.1.3 Gender:
The influence of the gender on the test scores in the model. If Significance (Sig.) <0.05 (Alfa) = Significant. From the data above 0.385 means the gender has no significant effect.

3.1.4 KAM:
Gender influence on test scores in the model. If Significance (Sig.) <0.05 (Alfa) = Significant. From the data above 0,000 means KAM has significant effect.

3.1.5 KAM*Gender:
Gender Influence * education on test scores in the model. If Significance (Sig.) <0.05 (Alfa) = Significant. From the data above 0,821 means learning model*KAM has no significant effect.

In order to see which KAM is significant, the after test of ANAVA (poshoc) is conducted as shown on table 4. Based on Table 4, the result shows that the significant difference of mathematical understanding enhancement occur between high KAM and middle KAM, and also high KAM and low KAM.

**Table 4.** Mathematical Understanding Enhancement Poshoc (Tukey) Test Based on KAM and Learning.

| (I) KAM | (J) KAM | Mean Difference (I-J) | Sig. | $H_0$ |
|---------|---------|------------------------|------|-------|
| High    | Middle  | 0.1778                 | 0.000| Rejected |
| Low     | Middle  | 0.2835                 | 0.000| Rejected |
| Middle  | High    | -0.1778                | 0.000| Rejected |
| Low     | High    | 0.1056                 | 0.020| Rejected |
| Low     | Middle  | -0.2835                | 0.000| Rejected |

The result of two way ANOVA test based KAM in Table 4 significance value less than 0.05 or p (sig)> 0.05, which means there are significant average enhancement of mathematical understanding ability between high, middle, and low KAM. The differences occur between high KAM, middle KAM and low KAM, or in other words the ability of student understanding between KAM high, middle and low different significantly.

3.2 Discussion
The results showed that students who learn to use the Cabri 3D spatial math abilities have an average higher than students who use conventional learning. This is possible because the results through the Cabri 3D learning, students are facilitated in building knowledge or mathematical concepts are built on spatial ability, so that students get a better understanding. For example, how students make assistive aids
or field lines in three dimensional space. Through assisted learning software Cabri 3D, students are given the opportunity to understand the distance between points in space, students learn to analyze how to measure the distance from point to point in space and how to count them with the approach of the conjecture the distance of the triangle. Cabri 3D spatial ability helps students to communicate the various transformations that they see. This is in line with Dahan's research, mathematics learning by using Cabri3D can improve students' problem solving abilities (Dahan, J, 2008)[12] & (Yuliardi, 2017)[13].

4. Conclusion

Based on the results; (1) The enhancement of student’s spatial abilities through Cabri 3D was higher than the conventional learning; (2) based on gender, there were no significant effect of student’s spatial abilities who exposed with Cabri 3D and conventional learning; (3) based on KAM, there was significant effect of student’s spatial abilities among ability of high, middle, and low KAM. The differences occur between high, middle and low KAM. (4) based on the questionnaire results, students' responses to the positive 3d cabri positive model, as much as 73.85% agree that learning Cabri 3D can improve understanding, interest and students' abilities to learn the concept of 3 dimensional geometry. Based on this result, mathematics learning Assisted Cabri 3D can be applied in the process of Mathematics learning in High School.

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Acknowledgements
I am enormously grateful to RISTEK DIKTI who has funded the research of this grant, thanks to our beloved family for the love and support of morale, colleagues and partner that helped us for the implementation of this research.