Research article

Computer-assisted learning using the Cabri 3D for improving spatial ability and self- regulated learning

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ABSTRACT

Spatial ability and self-regulated learning have broad implications for students. Therefore, this study aimed to determine the improvement of spatial ability and self-regulated learning of students who obtain computer-assisted learning using the 3D Cabri program. This quasi-experimental study with pre-test and post-test design involved 71 tenth grade high school students in Bandung, Indonesia. Furthermore, the experimental class obtained computer-aided learning using the Cabri 3D program, while the control obtained conventional learning using a scientific approach. The analysis discovered that (1) the improvement of students' spatial ability in the experimental class was better than those in the control class, (2) students of the experimental class achieved better spatial ability than those in the control class, (3) the improvement of students' self-regulated learning in the experimental class was better than those in the control class, and (4) students of the experimental class achieved better self-regulated learning than those in the control. These facts can help educators to consider the application of the Cabri 3D program in mathematics education in the future.

1. Introduction

In mathematics learning, it is important to use visualization, spatial reasoning, and geometric modeling to solve studying problems (NCTM, 2000). Geometry has broad implications for every student as it provides a natural environment for constructing geometric reasoning and proof (NCTM, 2000). In fact, it is employed to develop students' spatial skills, intuition, visualization, solve practical problems, and more (Fabiyi, 2017).

Many researchers have stated that spatial ability has an important role in understanding geometry (Güven and Kosa, 2008); Hartatiana et al. (2017a, b); Muntazhimah and Miatun (2018); Unal et al. (2009). Furthermore, the development of spatial abilities will enable students to easily understand mathematical and geometric problems (Kepceoğlu, 2018). Moreover, experiences related to geometric concepts that are obtained in the classroom enhance students' spatial abilities. Students who have high spatial skills can easily understand geometric shapes and the connections between the shapes (Baratti et al., 2020; Yani and Rosma, 2020). This finding clearly showed that mastery of spatial abilities has broad implications for students.

Nevertheless, it has been discovered that the spatial ability of Indonesian students is still low. Hence, they are unable to compete with others. This has been reflected in the results of the Trend evaluation in International Mathematics and Science Study (TIMSS) and the Program for International Student Assessment (PISA). The evaluation results showed that Indonesian students occupy the last 5 positions (Mullis et al., 2015; Schleicher, 2014, 2018). Furthermore, a thorough evaluation showed that the students' spatial ability was low (Widana, 2017). This is directly proportional to the low attention to spatial ability, which is closely related to geometry (Syahputra, 2013).

Determining the best method to develop students' spatial abilities seems to be the focus of studies in learning geometry to date. In fact, suggested learning highlights the importance of using computer technology media to improve students' spatial abilities (Balacheff and Kaput, 2018; Hohenwarter and Jones, 2007; Laborde, 2001; Renavitasari et al., 2018). Therefore, the integration of computer technology in education, especially in mathematics learning is important, and has become a trend to meet the challenges of the 21st century (Adelabu et al., 2019); Adelabu and Makgato, 2019; Azizul and Din (2016).

One of the computer-aided learning media that can explore geometry and spatial ability is the Cabri 3D program. Learning with this program allows users to create 3-dimensional shapes that can be manipulated. Furthermore, it facilitates students to understand concepts that are previously abstract or material that requires spatial ability (Nasongkhla et al., 2019). Therefore, the use of dynamic media such as Cabri 3D can reduce students' cognitive burdens by applying visualization that is easier to understand (Tejada and Serra, 2018).

Previously, there have been many studies examining the effectiveness of Cabri 3D program on students' spatial abilities (Güven and Kosa, 2008) (Hartatiana et al., 2017b; Hendriana et al., 2019; Muntazhimah and Miatun, 2018; Subroto, 2011; Syahputra, 2011). The studies were conducted using a computer model only as additional support, while the teacher was the main instructor. However, the research did not examine the affective abilities needed to support the use of computers in learning. Meanwhile, previous research on the importance of improving spatial ability involved the use of Mobile-Based Augmented Reality to improve students' understanding of 3-dimensional shapes. The results showed a significant improvement in spatial abilities (Rohendi and Wihardi, 2020).

Therefore, this study aimed to expand previous research that examined the effectiveness of Cabri 3D on spatial abilities. In a study conducted with a computer-based learning model using Cabri 3D program, the teacher acts as a facilitator, while students play an active role in understanding construction using the program. This model needs to be supported by the strong ability of students self-regulated learning. This type of learning is believed to play a key role in student success, academic life, and career (Ros et al., 2012; Žydžiūnaitė et al. (2014). Furthermore, the principle of self-regulated learning means that in teaching and learning activities, it needs to be developed as early as possible. The realization of this principle is to place teachers in the main role as facilitators and motivators (Mulyono, 2017; Lai and Hwang, 2016). However, research that collaborates learning with computers on spatial abilities has not been widely conducted.

Therefore, this study aimed to examine the effectiveness of the Cabri 3D on spatial abilities and self-regulated learning of students. In this case, the following questions were examined:

1) Analyzing the improvement of students' spatial ability using learning assisted by the Cabri 3D program, compared to using conventional learning.
2) Analyzing the achievement of students 'spatial abilities using the Cabri 3D program, compared to using conventional learning.
3) Analyze the improvement of student learning independence using the Cabri 3D program, compared to using conventional learning.
4) Analyze the achievement of student learning independence using the Cabri 3D program, compared to using conventional learning.

2. Materials and methods

2.1. Research design

The design used in this study was a quasi-experimental with two classes, namely the control and the experimental class. Furthermore, the quasi-experimental method was used because there are other variables that are difficult to control. The experimental group was treated with computer-assisted learning using the Cabri 3D program, and the control group used conventional learning. In this study, conventional learning refers to using a scientific approach in accordance with the 2013 curriculum applicable in Indonesia (Notodiputro, 2013).

At the beginning of the study, students were given a pre-test on spatial ability and Self-regulated learning. The researchers then provided learning according to the curriculum for six weeks. In the experimental class, Cabri 3D program was used as a learning medium for students in understanding the material. Furthermore, students try to work independently on some of the questions given during the learning activities using Cabri 3D program. Meanwhile, in the control class, the researchers provided learning using blackboard media and manual teaching aids in the form of cube models, blocks and other spatial shapes. At the end of the study, students were again given problems about spatial ability and learning independence in the form of a post-test.

In this quasi-experiment, subjects were not randomly grouped, but the researchers considered the suggestion proposed by Ary et al. (2010), which is to accept the subject's situation. Therefore, it does not interfere with school administration and management. The design used is described in the following pattern:

$$\frac{\textbf{01 X 02}}{\textbf{0} \quad \textbf{0}}$$

where:

01: Pre-test
02: Post-test
X: Computer-aided learning using the Cabri 3D

2.2. Sample

The target population was tenth grade students in one of the public schools in Bandung, which is well accredited (A) by the National Accreditation Body of Indonesia. A-accredited schools generally have adequate facilities such as computer laboratories, therefore they are appropriate to be used as research sites. Furthermore, the sample was selected using a purposive sampling technique. Class 10-MIA 1, which consisted of 35 people, was selected as the experimental group, while Class10-MIA 4, consisting of 36 people, was selected as the control. This is because the two classes had the characteristics that most represent the population. In order to explore information about the participants, a preliminary ability test was given on the flat-sided shape building material. The result scores were almost the same and in the low category. In addition, homogeneity test was implemented in both groups, and the results were comparable in terms of spatial ability.

2.3. Instrument

This study used a Mathematical Spatial Ability Test Instrument in the form of an essay test. The test form of description was implemented to explore students' spatial abilities and the indicators are: (1) Spatial Visualization; (2) Spatial Relations; (3) Spatial Perception, and (4) Spatial Orientation. Furthermore, the instrument was analyzed for validity using product correlation, and rough numbers. Reliability testing was also conducted using the Alpha Cronbach formula. Meanwhile, the test instrument consists of eight questions covering four indicators of spatial ability. In overcoming this problem, students were asked to provide reasons. The scoring of the test results referred to the North Carolina Math Rubric I, and the details are as listed in Table 1 below.

The self-regulated learning questionnaire included seven indicators, which are dependence, having self-confidence, creating learning plans, having sense of responsibility, behaving based on self-initiative, having self-control, and finding information.

The used SRL was adapted from (Zimmerman, 2002), which revealed several components or phases in learning independence, namely: (1) setting specific targets, (2) several strategies to achieve the set goals, (3)

Table 1. Guidelines for scoring the spatial capability instrument.

Score	Criteria
0	Not addressing the problem
1	Addressing the problem incorrectly
2	Addressing the problem correctly but having minor errors
3	All parts of the question are answered accurately and completely.

Table 2. Descriptive statistics of spatial ability.

	Experimental Class		Control Class		Gain Index Value	
	Pre-test	Post-test	Pre-test	Post-test	Experimental	Control
Mean value	19.37	26.71	19.00	24.94	0.68	0.54
Variance	8.95	7.15	5.83	6.34	0.07	0.05
Standard Deviation	2.99	2.67	2.41	2.52	0.26	0.22

Table 3. Results of analysis of similarity tests for spatial ability pre-test.

	Experimental	Control
Calculated t-value	0.57	
t-table	1.99	

measuring the results obtained from each learning improvement, (4) Organizing physical atmosphere and the environment in order to support the process, (5) time is used efficiently, (6) pay attention to what has been done, (7) correlate the results with the causes, and (8) adapt the next method.

3. Data analysis

This study used descriptive and inferential statistical analysis. Furthermore, hypothesis testing was conducted through the t-test with a significance level of 0.05, where the normality and homogeneity tests have been previously carried out. In addition, the Analysis tool was SPSS software.

4. Results

4.1. Spatial ability research results

Spatial ability tests were conducted twice, before and after the treatments were given to the experimental and control class. Table 2 below showed the descriptive statistics of spatial ability tests.

Based on Table 2, the mean pre-test score of the experimental class was 19.37, while the mean of their post-test was 26.71. Therefore, it can be seen that the spatial ability of students in experimental class had improved. Meanwhile, the mean pre-test score of the control class was 19.00, while the mean of their post-test was 24.94. It can be seen that the spatial ability of students in the control class had also improved. However, the mean post-test score of the experimental class was 26.71, while the mean post-test score of the control was 24.94. Therefore, it appeared that the spatial ability of the experimental class was higher than that of the control class.

The average gain index value of the experimental class was 0.68, while that of the control class was 0.54. Based on the gain index criteria according to Hake (1999), the quality of the improvement in spatial ability, both in the experimental and the control class was in the medium category. Therefore, it can be seen that the gain index value of the experimental class was higher than the control.

The analysis results of the similarity tests on the pre-test scores of the experimental and control class are presented in Table 3.

Based on Table 3, it can be seen that the calculated t-value was 0.57, while the value of t-table with a significance level of 5% was 1.99. Based on the testing criteria, H_0 is rejected. This means that there was no

significant difference in the average values of the initial spatial abilities of students in experimental and control class.

The analysis results of the differences in the two average values that had been conducted using the t-test on the gain index values of the experimental and control class are presented in Table 4.

Based on Table 4, it can be seen that the calculated t-value was 2.47, while the value of t-table with a significance level of 5% was 1.66. Based on testing criteria, H_0 is rejected. This means that the increase in the spatial ability of students in the experimental class is significantly better than those in the control.

The analysis results of the t-test for the difference in the two mean values of the experimental and control class post-test score are presented in Table 5.

Based on Table 5, it can be seen that the calculated t-value was 2.87, while t-table with a significance level of 5% was 1.66. Based on testing criteria, H0 is rejected. This means that the average spatial ability score of students in the experimental class was greater than those in control.

4.2. Study results of self-regulated learning

The self-regulated learning questionnaire was distributed twice, before and after the treatment was given to the experimental and control class. A summary of this information is presented in Table 6.

Based on Table 6, the average value of self-regulated learning of the experimental class was 79.87, while the value of the control class was 75.55. It appeared that the self-regulated learning achieved by the experimental class was higher than what is achieved by the control class. Furthermore, the average gain index value of self-regulated learning in the experimental class was 0.16, while it is 0.08 in the control class. Based on the gain index criteria according to Hake (1999), the values showed that both groups were included in the low criteria. Therefore, it can be seen that there was a difference between the average of the two data. In addition, improvement of the experimental class was higher than the control.

The t-test analysis results of the differences in the two average post-test scores of the experimental and control class are presented in Table 7 below.

Based on Table 7, it can be seen that the calculated t'-value was 3.40. Meanwhile, the value of Cochran-Cox's t-value was 1.69. Based on testing criteria, H_0 is rejected. This means that the improvement of self-regulated learning of the experimental class was better than the control class.

The analysis results of the t-test for difference in the two mean scores of the experimental and control class are presented in Table 8.

Based on Table 8, it can be seen that the calculated t'-value was 1.92, and the Corhan-Cox's t-value was 1.69. Based on testing criteria, H_0 is rejected. This means the self-regulated learning achieved by the experimental class students was better than those in the control class.

Table 4. Analysis results of tests for difference in the average gain index values of spatial ability.

	Experimental	Control
Calculated t-value	2.47	
t-table	1.66	

Table 5. The analysis results of the t-test for difference in the two mean values of spatial ability post-test.

	Experimental	Control
Calculated t-value	2.87	
t-table	1.66	

Table 6. Descriptive statistics of self-regulated learning.

	Post-test		Gain Index Value	
	Experimental	Control	Experimental	Control
Mean Value	79.87	75.55	0.16	0.08
Variance	135.38	41.93	0.01	0.01
Standard Deviation	11.64	6.48	0.11	0.07

Table 7. The analysis results of the t-test for difference in the two mean values of self-regulated learning gain index values.

	Experimental	Control
t'	3.40	
Cochran-Cox's t-value	1.69	

Table 8. The analysis results of the t-test for difference in the two mean values of final self-regulated learning.

	Experimental	Control
t'	1.92	
Cochran-Cox's t	1.69	

(a)

(b)
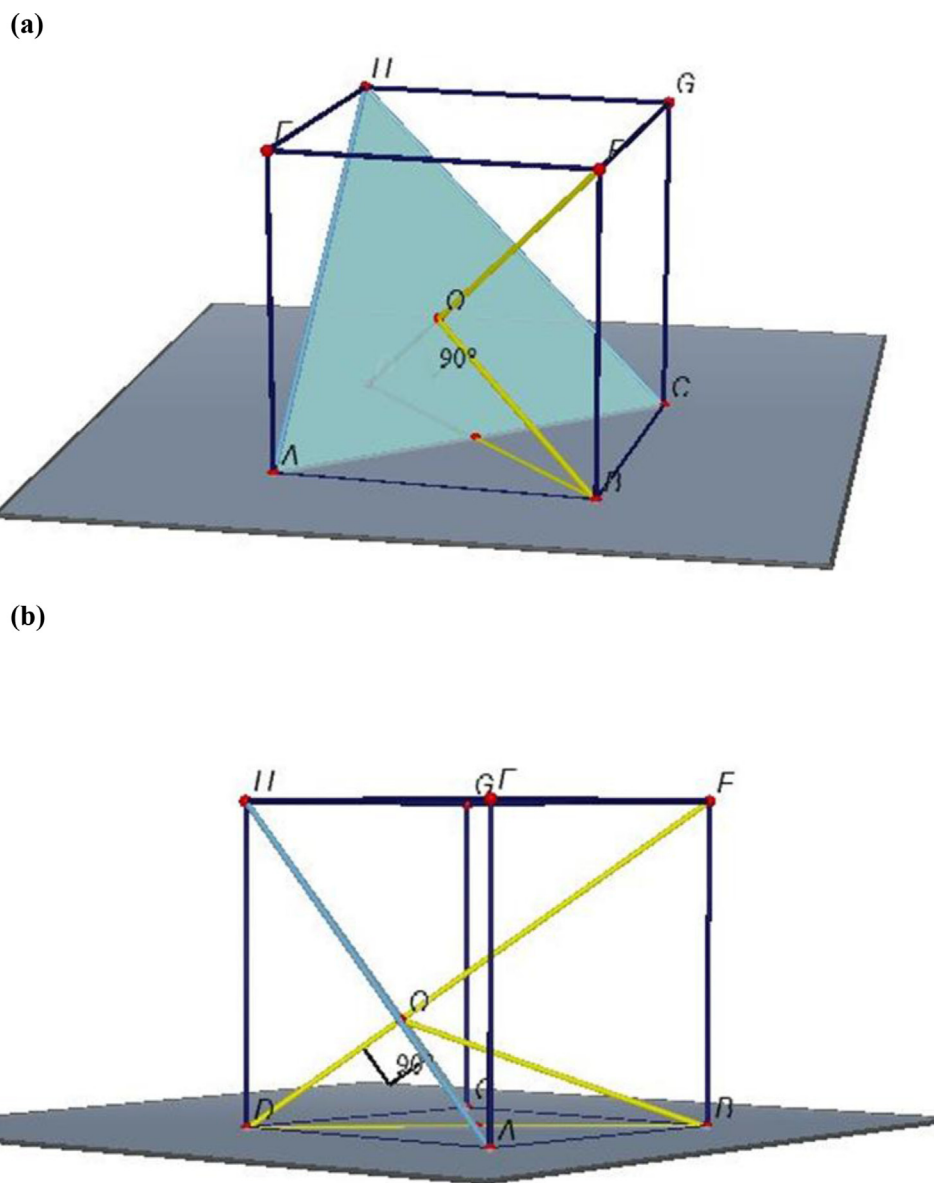
Figure 1. Visualization of Distance from point D to the plane ACH in the Cabri 3D.
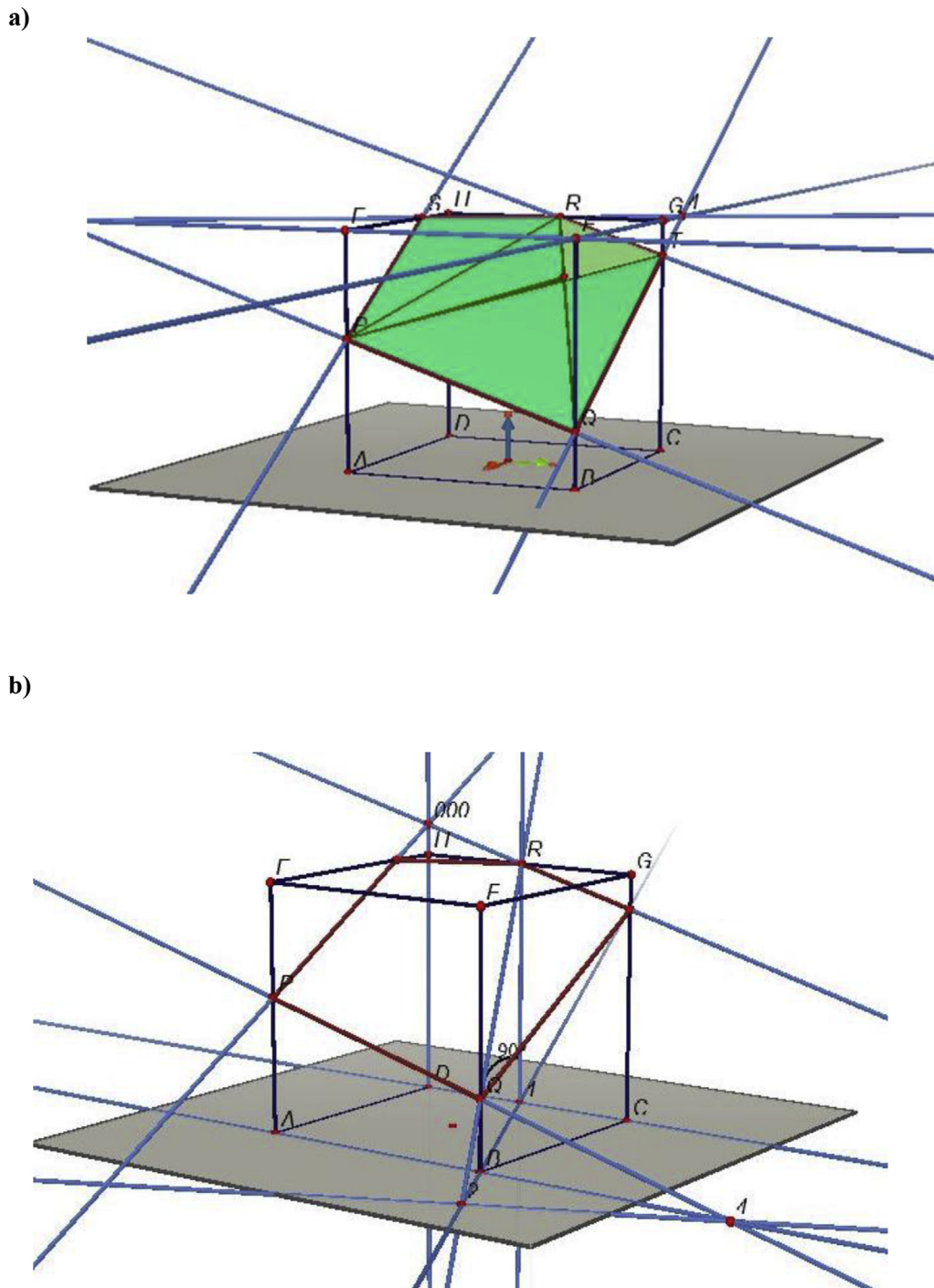
a)

b)

Figure 2. A cutting plane passing through points in P, Q, and R.

5. Discussion

The analysis results showed that the improvement and achievement of spatial abilities of experimental class students who received computer-aided learning using Cabri 3D were higher than those that received conventional learning. This finding is consistent with the results of previous studies, which discovered that Cabri 3D-assisted learning significantly improved students' spatial abilities (Adelabu and Makgato, 2019; Baki et al., 2011; Güven and Kosa, 2008; Hartatiana et al., 2017a, 2017b; Kepceoğlu, 2018; Muntazhimah and Miatun, 2018). This is possible because learning with the program may facilitate difficulties related to spatial abilities. Also, the Cabri 3D is a program that relies on dynamic

modeling which helps the process of manipulation and provides experience in a visual form (Starčič et al., 2015). This finding also supports the assumption of Anthony (2006), that the program plays an important role in learning geometry by using the available facilities to change the point of view or manipulate objects into animated motion.

By using this program, students' understanding of concepts can be improved. For example, an explanation of an infinite plane can easily be delivered by creating a plane on the program worksheet and an infinite plane will be presented to students. Meanwhile, when an explanation is given without the program, then all that can be done is to provide information that the plane is infinite. This is because of the limitations to show that a plane is infinite. Another benefit of using the Cabri 3D is to

develop imagination in order to improve visualization abilities. By using the program, imagination can be realized by exploring what is imagined. However, this will be difficult without using the Cabri 3D. Also, this program has great potential to remove student limitations from manipulating 3D models, which have a very large role in spatial ability (Güven and Kosa, 2008).

Learning by using Cabri 3D can help students to understand concepts and solve three dimensional problems, such as distances, angles, and cutting planes. Therefore, when teaching the concept of distance and angle, the program can be used to describe right triangles which can help in determining distance and magnitude of angles. These are then followed by the application of the Pythagorean theorem, area of triangle, or trigonometry. At first glance, the process looks the same, which is drawing a triangle that can help find distance. The difference is only in the working media, which are paper and Cabri 3D. Therefore, a task that cannot be performed using conventional learning can be performed using a 3D Cabri worksheet. Figure 1 showed an illustration of the results of student work in determining the distance from point D to the ACH plane.

In Figure 1, after drawing line segments to determine triangles, such as in Figure (1a), which will help calculate distances using the Pythagorean theorem and area of the triangle, the image can be rotated such that the point at which a triangle has right angles can be determined. Therefore, it can help the calculation process by using the area of triangle or the Pythagorean theorem, as shown in Figure (1b). It can also be used to determine the angle.

In learning to determine the cutting plane, it seems the process of drawing the affinity axis is moved from paper to the Cabri 3D worksheet. In fact, the program provides more benefits than that. By using the rotation feature, the intersection of the affinity axes can be seen from various angles, therefore it can be known whether they really intersect or are only parallel. Also, misperception of two intersecting lines as parallel lines often occurs in conventional learning. Figure 2 below showed the student work in drawing the cutting plane on the Cabri 3D worksheet.

In Figures 2, (2a) and (2b) are illustrations of the same cutting plane, but the affinity axis was drawn using a different method. In figure (2a), there is an ($\overline{EF}$) extension and ($\overline{RT}$) that are two parallel lines which will be easily identified when the plane is drawn on the Cabri 3D worksheet by utilizing the rotation feature. Meanwhile, when the plane is presented in conventional learning, it will appear that the line ($\overline{EF}$) and ($\overline{RT}$) intersect. In figure (2), there is intersection of two lines that appear to be far away. Furthermore, when the plane is drawn on the Cabri 3D worksheet, the rotation feature can be used to determine the intersection of the two lines. Meanwhile, when the plane is drawn conventionally, it will require a large-sized drawing medium.

From the test results in the experimental class, there were six students (17.14%) whose spatial ability scores were below the mean score of the control class. This means that there were still shortcomings in the learning process, such as lack of maths exercise worksheet that can explore spatial abilities.

Furthermore, based on the results of data processing, there were greater improvement and achievement of self-regulated learning in students from the Cabri 3D class than those from the control class. This may be because computer-assisted learning can support the indicators of self-regulated learning. Furthermore, the indicators of self-regulated learning are closely related to each other.

Computer-aided learning can reduce students' dependence on others because they can independently explore and find information about the problem, and try to solve the problem by themselves. This process can be repeatedly done unlike in conventional learning (Prabhu and Subramonian, 2019). Meanwhile, Kustandi et al. (2020) stated that blended learning combined with technology can help students develop metacognitive attitudes, motivations, and be active in their learning behavior. The results showed that most students who participated in blended learning had positive self-confidence.

Therefore, students can make their own learning plans without having to depend on others. Furthermore, they will develop independent learning skill, which is a skill to pay attention in supervising, showing, and regulating their goals to add information, develop expertise, and develop themselves (Putri et al., 2020; Peel, 2020). This can create self-confidence, sense of responsibility, and self-control. In addition, based on mathematics based learning media, technology can encourage students to think, generate new ideas, focus, be active and be independent in all teaching and learning activities (Sumarwati et al., 2020).

6. Conclusions

Based on the results of the study conducted on spatial ability and independent learning skill using the Cabri 3D program and conventional learning, it can be concluded that:

1) The improvement of spatial ability of students who learned with Cabri 3D program was better than those who received conventional learning.
2) Students who learned with Cabri 3D program achieved better spatial ability than those who received conventional learning.
3) The improvement of self-regulated learning of students who learned with Cabri 3D program was better than those who received conventional learning.
4) Students who learned with Cabri 3D program achieved better self-regulated learning than those who received conventional learning.

The results of this analysis showed the advantages of Cabri 3D in improving spatial ability and self-regulated learning. However, these findings are based on studies conducted in schools with adequate facilities. In fact, the number of schools that have complete facilities in Indonesia is limited. Therefore, further research is needed with a wider scale and different schools, as well as different variations inabilities. There are still a small proportion of students whose spatial abilities are below the control class average. Therefore, a more qualitative-oriented study seems necessary to delve deeper into students' learning difficulties.

Declarations

Author contribution statement

Nurjanah: Conceived and designed the experiments; Performed the experiments; Wrote the paper.

B. Latif: Performed the experiments; Analyzed and interpreted the data; wrote the paper.

Ricki Yuliardi: Contributed reagents, materials, analysis tools or data; Wrote the paper.

Maximus Tamur: Analyzed and interpreted the data; Wrote the paper.

Data availability statement

Data included in article/supplementary material/referenced in article.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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