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Discovery Learning Versus Traditional Learning: How Effective Discovery Learning Can Improve Mathematical Creative Thinking Skills

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Abstract

The present study aims to understand the effectiveness of discovery learning in increasing mathematical creative skills in comparison with traditional learning methods. This study uses a non-equivalent control group research design. The variables in this study include independent variables, namely Discovery Learning and Traditional Learning, and the dependent variable is the mathematical creative thinking skill, while the control variable is a group of students' initial ability levels (top, middle, and bottom). The research sample consisted of two groups of 39 grade 7 students selected using a random assignment technique from one junior high school in Lembang, Indonesia. The data were obtained through mathematical creative thinking skills tests. Overall, the improvement in mathematical creative thinking skills of students who received Discovery Learning is better than students who received traditional learning. In the top and middle levels, the improvement of mathematical creative thinking skills of students who received Discovery Learning is better than students who received traditional learning. While the groups are in the bottom level, the mathematical creative thinking skills of students who get discovery learning are no better than students who get traditional learning.

Keyword: Discovery Learning, Mathematical Creative Thinking Skills, Traditional Learning

Abstrak

Penelitian ini bertujuan untuk memahami keefektifan dari Discovery Learning dalam meningkatkan kemampuan berpikir kreatif matematis dibandingkan dengan metode pembelajaran tradisional. Penelitian ini menggunakan desain penelitian grup kontrol non-ekuivalen. Variabel bebas dalam penelitian ini adalah Discovery Learning dan Pembelajaran Tradisional, variabel terikatnya adalah kemampuan berpikir kreatif matematis, dan variabel kontrolnya adalah kelompok kemampuan awal siswa (atas, tengah, bawah). Sampel penelitian terdiri dari dua kelompok kelas 7 dari salah satu sekolah menengah pertama di Lembang, Indonesia, masing-masing beranggotakan 39 siswa dengan menggunakan teknik random assignment. Data diperoleh melalui tes kemampuan berpikir kreatif matematis. Secara keseluruhan, peningkatan kemampuan berpikir kreatif matematis kelompok siswa yang memperoleh perlakuan DiscoveryLearning lebih tinggi dibandingkan kelompok siswa yang

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memperoleh perlakuan pembelajaran tradisional. Pada kategori siswa atas dan tengah, kemampuan berpikir kreatif matematis siswa yang memperoleh Discovery Learning lebih tinggi dibandingkan dengan siswa yang memperoleh perlakuan pembelajaran tradisional. Sedangkan pada kategori bawah, kemampuan berpikir kreatif matematis siswa yang memperoleh perlakuan Discovery Learning tidak lebih baik daripada siswa yang memperoleh perlakuan siswa yang memperoleh perlakuan pembelajaran tradisional.

Kata kunci: Discovery Learning, Kemampuan berpikir kreatif matematis, Pembelajaran Tradisional

Introduction

The aim of developing the 2013 Curriculum is to increase Indonesia's achievements in the international assessment known as Trends in International Mathematics and Science Study (TIMSS). The reason why results from TIMSS are essential is that it is used as a consideration in developing regulations. TIMMS results in Indonesia is one of the main reasons why Indonesia keeps developing and reforming its curriculum.

The present study attempts to analyze Indonesia's achievement in this international assessment. The analysis was conducted by examining the examples of the questions in the assessments and Indonesia's achievement in comparison with other participating countries. Solving this high-level problem requires the ability to reason, solve problems, think creatively, and critically. As shown on the TIMMS report in 2011(Mullis et al., 2011):

"*Students can reason with information, draw conclusions, make generalizations, and solve linear equations. Students can solve a variety of fraction, proportion, and percent problems and justify their conclusions. Students can express generalizations algebraically and model situations. They can solve a variety of problems involving equations, formulas, and functions. Students can reason with geometric figures to solve problems. Students can reason with data from several sources or unfamiliar representations to solve multi-step problems*".

An example of the TIMSS question is as follows:

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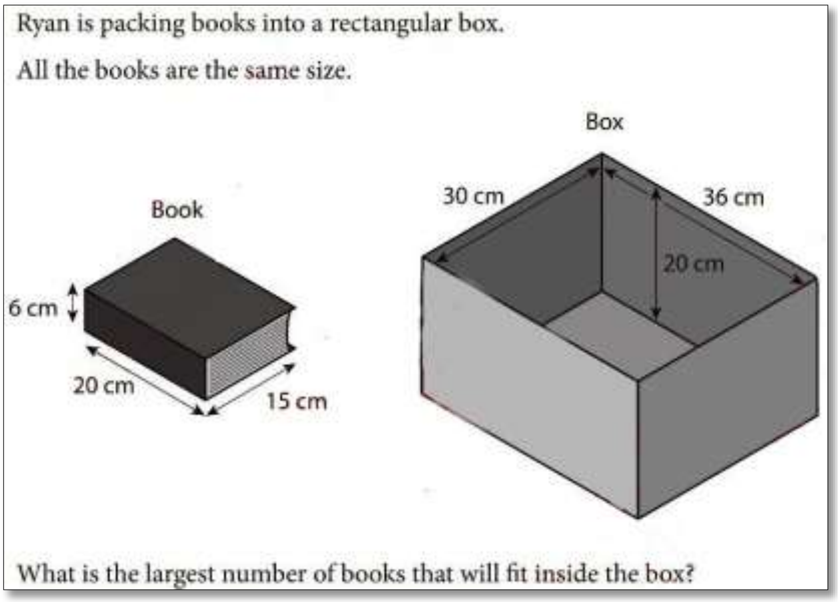

Figure 1. Example of High-Level Thinking Problem in TIMMS: 2011 (Example 1)
Sources: (Mullis et al., 2011)

The question above requires the students to first find the composition of the book placements in order to figure out the highest number of books that can be inserted into the box. The most straightforward placement is by placing them vertically in the box or through a combination of vertical and horizontal placement. In order to solve the problem, creativity skills are required to identify several possibilities of book placement and figure out the best placement as the answer. The illustration is as follows:

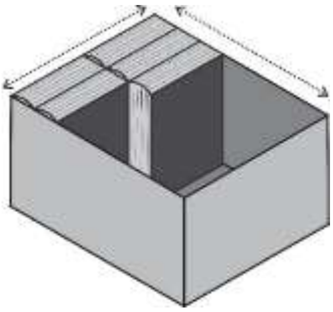

Figure 2(a). Placement of Books in the Box (Illustration 1)

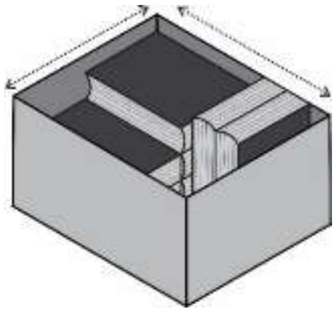

Figure 2 (b). Placement of Books in the Box (Illustration 2)

From the international score, which was 25%, Indonesia only achieved 11% for the sample question above. This means that only 25% of the students internationally were able to answer this question, while in Indonesia, there were only 11%. The results indicate the gap in the ability of Indonesian students in comparison to participants from other countries, especially with the top five countries whose scores were all above 50%.

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From the abovementioned points, then it is clear that there is a considerable gap between the desired and required curriculum with reality. Focus on this gap; the 2013 Curriculum comes with aims to develop the students in a way that would allow them to think and act effectively and creatively in both concrete and abstract areas(Kemendikbud, 2012). Generally, the curriculum aims to prepare Indonesian students to have the ability to live as individuals and citizens who are productive, creative, innovative, and active and also able to contribute to their society, nation, and world civilization.

From all the available learning models, methods, and strategies, discovery learning is one of the learning strategies that may bridge the existing gap and is in line with the aim of the 2013 Curriculum. During discovery learning, students are given a situation where they have to find out independently the main contents of the learning, which are not told explicitly to them before the start of the learning process(Abrahamson & Kapur, 2018; Rahman, 2017; Zeeman, 1966). By providing students with this situation, their reasoning skills(Khomsiatun, S. & Retnawati, 2015; Hammer, 1997), problem-solving skills(Siregar & Marsigit, 2015), critical thinking (Noer, 2018;Farib et al., 2019), and creative thinking (Rochani, 2016)are developed. Discovery learning also provides opportunities for students to improve their mathematical creative(Martaida et al., 2017).

Treffinger (1980)found that creativity is related to the discovery process. According to Treffinger(1980), experiences through discovery learning may increase creativity skills by pushing the students to manipulate their environment actively and generate new ideas. Treffinger (1980) also stated that the creative processes (i.e., fluency, flexibility, elaboration, and authenticity) are incorporated into the inquiry-discovery teaching approach. This teaching approach invites the student to find the essential concepts instead of telling them directly(Pontual da Rocha Falcão, 2014). By doing so, students may be able to find the concepts by themselves through the learning processes that are provided by the teachers.

Grykiewicz (Isaksen et al., 2011; Zeeman, 1966) describes creativity as a conception of various aspects involving "divergent and convergent thinking, problem discovery and problem solving, self-expression, intrinsic motivation, curiosity, and self-confidence". Tamadge concludes that creative thinking is the ability to see new relationships between techniques and application areas and make connections between ideas that may not be related(D. W. Haylock, 1987).

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A Russian psychologist, Krutetskii, characterizes creativity in the context of problem formation (problem discovery), discovery, freedom, and authenticity(D. Haylock, 1997), and other experts add fluency, flexibility, elaboration, and authenticity to mathematics (D. Haylock, 1997).

Discovery learning also has many characteristics that are in line with the scientific learning approach. Both these approaches attempt to teach students to recognize and formulate a problem, test the hypothesis of a problem by conducting an investigation and ending the learning process by drawing and presenting their conclusions(In'am & Hajar, 2017). During discovery learning, some aspects of the learning experiences require extra attention(Fasco, 2001): 1) Providing initial experiences to pique students' interest to probe about the problems, concepts, situation or idea; 2) Providing situations that they can manipulate and materials that would assist them to start exploring; 3) Providing information sources for students' questions; 4) Providing the materials and tools that would trigger and encourage discovery learning and students' outcomes; 5) Providing time for students to manipulate, discuss, try, fail, and succeed; 6) Providing guidance, guarantees, and reinforcements for students' ideas and hypotheses; and 7) Respect and encourage an acceptable solution strategy, this would create a positive climate that would support the best results.

According to the Ministry of Education and Culture(2013a), discovery is made through observation, classification, measurement, prediction, determination, and inference. Discovery learning consists three characteristics(Hoffman, 2000): 1) Through the exploration activities and problem-solving, students create, integrate, and generalize knowledge; 2) Students can control and determine the sequence and frequency of learning; 3) Activities are aimed at encouraging the integration of new knowledge into the knowledge base that are already possessed by the students.

There have been many studies conducted to see how discovery learning can stimulate and improve students' high order thinking skills, such as creative and critical thinking skills. The studies were carried out in the context of various branches of science, including physics (Rahman, 2017;Syolendra & Laksono, 2019), languages (Wahyudi et al., 2019; Kusumawardhani et al., 2019), chemistry(Rudibyani & Perdana, 2018; Rudibyani, 2018), and mathematics (Ratnaningsih, 2017;Yuliani et al., 2018).Therefore, the present study aims to

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understand the effectiveness of discovery learning in increasing mathematical creative skills in comparison to traditional learning methods. The results of this study are expected to serve as a reference for teachers in choosing the appropriate learning styles for their class as creative skills are as crucial as other mathematical skills, the selection of models, methods, or learning approaches that are not very appropriate may result in the learning outcomes that are not very maximized. If discovery learning becomes an option for teachers in improving creative mathematical skills, then this research may provide insight into what approaches might be implemented to deliver the desired learning effectiveness.

Based on the background that has been described previously, the formulation of this research problem is:

1. Is the increase in mathematical creative thinking skills of students who get Discovery Learning better than students who get conventional learning, in terms of a) overall, and b) the students' initial abilities (top, middle, bottom)?
2. Is there an interaction between the learning factors that are given by the students 'initial ability factors to increase students' mathematical creative thinking skills?

Method

The variables in this study include independent variables, namely Discovery Learning and Traditional Learning, and the dependent variable is the mathematical creative thinking skill, while the controlled variable is a group of students' initial ability levels (top, middle, and bottom).

Subjects were chosen based on groups that were formed previously by the school. Then from all groups in grade 7, two random groups were taken, the two groups each had 39 students, one as an experimental group (receiving discovery learning treatment) and one as a control group (receiving the traditional treatment), this technique is commonly referred to as a random assignment(Borg & Gall, 1989). This is possible because, there are no superior class groups in schools, the division of class groups is made as homogeneous as possible based on the final grade examination of elementary schools.

This study used a non-equivalent control group research design. In this design, there were pretest, treatment, and posttest. Pretest and posttest were given to both groups (discovery learning and traditional learning), while treatment was only given to the

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discovery learning group.

The experimental design of this study was as follows:

R :	O	X	O
R :	O		O

(Borg & Gall, 1989)

Note:

X: The discovery learning treatment

O: Pretest and posttest

R: Random assignment

The population of this study was grade 7 students of one junior high school in Lembang, West Java, Indonesia. The research sample consisted of two groups, one group as the experimental group that received the discovery learning treatment and the other group as the control group that received the traditional learning treatment. The two groups each had 39 students.

The initial procedure was to make a grid and design an instrument, then an assessment by people who are considered as experts. Experts, in this case, refer to weighers who are competent to validate research instruments and provide input or suggestions that can be used to improve the instruments that have been prepared.

The aspects assessed in the ability to think mathematically creative are fluency, flexibility, elaboration, and authenticity. Data on mathematical creative thinking ability is obtained through students' answers to each item. The scoring criteria use a rubric developed by Brookhart(2001).

Table 2. Scoring Guidelines for Students' Mathematical Creative Thinking Ability Tests

Aspect	Student Response	Score
Fluency	No answer	0
	Put forth ideas that are not relevant	1
	Put forward an idea that is relevant to solving the problem, but the disclosure is unclear	2
	Put forward a relevant idea and express it clearly	3
	Put forward more than one idea that is relevant to solving the problem but the disclosure is unclear	4
	Put forward more than one idea that is relevant to the solution of the problem and its disclosure is clear	5
Flexibility	No answer	0

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Aspect	Student Response	Score
	Submitting answers with one or more ways of solving them all wrong	1
	Submitting answers in one way and there are errors in the process so the results are wrong	2
	Submitting answers in one way and the process is correct and the answer is right	3
	Submitting answers in more than one way but there is a mistake in the process, so the results are wrong	4
	Give answers in a variety of ways and the process is correct and the results are right	5
Originality	No answer	0
	Give the wrong answer	1
	Provide a way to resolve it in a different but less clear way	2
	Provide a different way of completion, the process has led to the correct answer but not completed	3
	Provides a different way of solving, but there are errors in the process, so the results are not right	4
	Provide a different way of completion, the process of completion and the results are correct	5
Elaboration	No answer	0
	Give the wrong answer	1
	There was a mistake in expanding the situation without the details	2
	There was a mistake in expanding and accompanied by less detailed details	3
	Expanding the situation correctly and detailing it in less detail	4
	Extending the situation correctly and detailing it in detail	5

Adapted from (Nikmah, 2017)

Tests for the content validity and face validity were carried out by weighers who are considered experts and have teaching experience in the field of mathematics education. The results of the consideration of content validity and face validity were analyzed using C-Cochran statistics to see whether the weighers considered each item about the ability to think creatively mathematically in terms of content validity and face validity equally or uniformly.

Results

This study used students' initial abilities as controlled variables. After the normality test, the initial ability data of the discovery learning group students and traditional groups were not normally distributed. Therefore, the two-difference test used was a non-parametric

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Mann-Whitney statistical test. The Mann-Whitney test concluded that the initial ability between students who obtained Discovery Learning, and students who obtained traditional learning did not differ significantly. So, it can be interpreted that both classes have relatively similar mathematical initial abilities.

The normalized gain data on the mathematical creative thinking ability of the Discovery Learning group was obtained from 39 students with a total score of 25.4. The average normalized gain of mathematical creative thinking ability for the Discovery Learning group was 0.65, the lowest score was 0.09, and the highest score was 1. The normalized gain data for traditional groups had a total score of 19.5. The average normalized gain for the traditional group was 0.5, with the lowest score was 0.1, and the highest score was 0.92.

The average normalized gain of the mathematical creative thinking ability of the Discovery Learning group was different from the average normalized gain of the mathematical creative thinking ability of the traditional learning group. The average normalized gain for the Discovery Learning group was higher than the average normalized gain of the traditional learning group.

The average normalized gain of the Discovery Learning group was 0.65 so the quality of the mathematical creative thinking ability improvement of students who received mathematics learning with Discovery Learning was medium. Furthermore, the average normalized score of traditional groups was 0.5, which showed that the creative thinking ability improvement of students who received mathematics learning with traditional learning was also medium. Through the normalized gain data, the composition of normalized gain interpretation for each group could be found. ***Normalized Gain Data Normalization***

Based on Table 5, the significance value obtained from the Discovery Learning group was 0.105, and the traditional group was 0.252, both of which were greater than 0.05, which means that both sample groups came from populations that were normally distributed. Then the homogeneity test was performed using the Lavene test.

In addition, a normality test for the normalized gain data of the top level students using the Shapiro-Wilk test with a significance level of 5%. The significance value of the normalized gain score from top level students from both Discovery Learning and traditional

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learning groups was higher than 0.05, so that H_o was accepted. Therefore, for the top level continued with a homogeneity test using the Lavene test.

Normality test on normalized gain data of middle level students using the Shapiro-Wilk test with a significance level of 5%. The significance value of the normalized gain score of students in the middle level of the Discovery Learning and traditional groups was higher than 0.05, so that H_o was accepted. Therefore, for the middle level continued with homogeneity testing using the Lavene test.

Normality tests on normalized gain data for lower level students using the Shapiro-Wilk test with a significance level of 5%. The significance value of the normalized gain score of students under the Discovery Learning and traditional learning group was higher than 0.05, so that H0 was accepted. This means that the normalized data gain for the discovery learning group and the traditional group were normally distributed. Therefore, for the lower level continued with the homogeneity test using the Lavene test.

Homogeneity of Normalized Gain

From the Lavene test results obtained a significance value of 0.581, which was higher than 0.05, so that $H_0\colon \sigma_1^2 = \sigma_2^2$ was accepted. In other words, the assumptions of the two variances were equally met, so we can test two averages using the t-test for the overall normalized gain data.

Difference Two Normalized Gain Data

Because the Lavene test results stated that the assumptions of both variances were equal (equal variances assumed were met), the authors use the results of the t-test of two independent samples with the assumption that both variances were assumed equal. Based on Table 11, the significance value (2-tailed) was 0.004. As the researcher conducted a one-tailed hypothesis test, the p-value (2-tailed) must be halved into $\frac{0{,}004}{2} = 0{,}002$, with 0.002 <0.05, so that H_o was rejected. It can be concluded that the average score of Discovery Learning normalized gain was better than the average score of normalized gain of traditional learning groups.

Then the normalized gain score was tested based on the students' initial ability levels. The results of two independent sample t-tests with the assumption that both variances were

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assumed equal to each level. Because the researcher conducted a one-tailed hypothesis test, the p-value (2-tailed) must be divided into two, with a significance value of the top and middle levels lower than 0.05, H_o was rejected. The significance value of the bottom level was higher than 0.05, so Ho was accepted. It can be concluded that for the top and middle levels, the average score of the normalized gain of the Discovery Learning group was better than the average score of the traditional learning group.

Interaction between Students' Initial Ability and Learning Factors on Increasing Mathematical Creative Thinking Ability

ANOVA Statistical Test was conducted to see the direct effect of two different treatments on increasing mathematical creative thinking skills as well as the interaction between learning conducted on students' initial abilities. The results of the General Linear Model (GLM) -Univariate variance analysis test performed at a significance level of 5% (α = 0.05), the summary was presented on Table 12 below.

Table 12. Two-Way ANOVA Test Results of Normalized Gain
Based on Student Learning and Initial Ability

Source	Type III Sum of Squares	df	Mean Square	Sig.
Learning	1,846	2	0,923	0,000
Student' Initial Ability	0,271	1	0,271	0,003
Learning * Student' Initial Ability	0,013	2	0,006	0,806
Total	30,189	78		

The hypothesis about the effect of students 'initial ability was used to state whether there was a difference in the increase in mathematical creative thinking skills caused by students' initial abilities (top, middle, and bottom) without regards to other factors. The hypothesis about the interaction between students 'initial abilities and learning factors was used to state whether there was a significant interaction between students' initial abilities and learning factors.

After calculating the two-way ANOVA, the results of which can be seen on Table 12, the significance value (sig.) obtained for the influence of the student's initial ability was 0.003. As it was higher than α = 0.05, so the null hypothesis was rejected. This means that there were differences in the improvement of mathematical creative thinking skills between students in the upper, middle, and lower levels. However, through the above table, it is not

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yet possible to determine which pair of ability levels differ in their ability to develop mathematical creative thinking. Therefore, a Tukey test was performed to analyze the differences in the improvement of mathematical creative thinking skills between top, middle, and bottom levels of students. The following were the results of Tukey's test calculations using SPSS.

The significance value for each combination of the initial ability level pairs was lower than 0.05, which suggests that the three initial ability levels had a significant difference in the increase in mathematical creative thinking skills. The students with the top ability level have the highest increase in mathematical creative thinking skills compared to students in the middle and lower levels. On the other hand, students in the lower ability level had the lowest increase in mathematical creative thinking skills.

The significance value obtained for the interaction between students' initial ability and learning factors on the ability to think creatively was 0.806, with 0.806> 0.05, so H_0 was accepted. This means that there is no significant interaction between discovery learning with students 'initial ability to increase students' mathematical creative thinking skills. In other words, the increase in mathematical creative thinking skills that occurred in Discovery Learning and traditional learning was not influenced by students' initial abilities.

Conclusion and Disscussion

In answering the first problem statement, this study provides the results that, overall, the improvement in mathematical creative thinking skills of students who received Discovery Learning was better than students who received traditional learning. Although the overall improvement in mathematical creative thinking ability of students who received Discovery Learning was higher than students who received traditional learning, the quality of improvement in both groups was at the medium qualification. The quality of improvement that was still within one qualification indicated the difference in improvement was not too far away. Teachers need to be more careful in correlating the types and context of the issues raised in Discovery Learning with the schemes that students have. In other words, teachers are required to be more familiar with student characteristics.

The results of this study are in line with studies conducted by Ubaidah and Aminudin (2019) which provide results that discovery learning provides positive results for increasing

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mathematical creative thinking abilities. Even the study conducted by Yuliani et al. (2018) indicated that the increase in mathematical creative thinking ability of students who obtained discovery learning was in the moderate category, which, as per the study in this paper.

In the top and middle levels, the improvement of mathematical creative thinking skills of students who received Discovery Learning was better than students who received traditional learning. On the other hand, the groups in the bottom level, the mathematical creative thinking ability of students who received discovery learning was no better than students who received traditional learning. This finding indicates that in order for Discovery Learning to work effectively, it requires students to already have a relatively good mathematical ability. In order for the students to be able to follow the stages of discovery as shown in the learning process, students must be equipped in advance by some particular mathematical skills at a certain level. However, because this research does not underlie this, other educational researchers can analyze what basic mathematical abilities students should master so that discovery learning can be applied more effectively.

In answering the second problem formulation, this study produced no interaction between learning factors and the levels of students' abilities towards increasing mathematical creative thinking skills. Because the two-way ANOVA results showed no significant indication, the study continued with Turkey's test. The results of Turkey's test show that only students with low levels have increased mathematical creative thinking abilities lower than others (top and middle).

This second result raises the question of why this can happen to students with low levels. Based on studies conducted by Wilke and Straits (2001), discovery learning may improve student achievement is because instead of only lower-level recall of factual information, it promotes higher-level thinking skills (e.g., application, analysis, synthesis, and evaluation). Students with low levels have the possibility of not mastering lower-level recall of factual information so that they experience greater difficulty in participating in discovery learning than students with middle and top levels. Even so, discovery learning still has a positive influence, at least in improving learning outcomes and student motivation (Saridewi et al., 2017).

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