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Mathematical Conceptual Understanding of Grade VIII Students Through Discovery Learning Assisted by eXeLearning

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Abstract

Students' mathematical conceptual understanding is a fundamental component in learning mathematics. It plays a crucial role in solving problems and developing higher-order thinking skills. However, previous studies and preliminary observations indicate that students still experience significant difficulties in understanding and applying mathematical concepts effectively. Therefore, innovative instructional approaches are needed to address this issue. This study aims to examine the development of students' mathematical conceptual understanding and to determine its significance among students taught through a Discovery Learning model assisted by eXeLearning, compared to a conventional learning approach. A descriptive and quasi-experimental design was employed by using a Non-Equivalent Post-test Only Control Group Design. The population consisted of nine eighth-grade classes at one public junior high school in a city, from which two classes were selected through simple random sampling: Class VIII.1 as the experimental group and Class VIII.3 as the control group. The research instruments included essay-based quizzes and a post-test measuring students' mathematical conceptual understanding. The quiz results showed a gradual increase in students' conceptual understanding across learning sessions. Post-test data were analysed using an independent samples t-test. The results of the independent samples t-test indicated that students who learned using Discovery Learning assisted by eXeLearning achieved significantly higher mathematical conceptual understanding than students who learned through conventional instruction. These findings suggest that integrating Discovery Learning with digital learning media such as eXeLearning can effectively support students in constructing and strengthening their mathematical conceptual understanding.

Keywords: Conventional Learning Model, Discovery Learning, eXeLearning, Mathematical Conceptual Learning

Introduction

Mathematical conceptual understanding is a crucial foundational ability that students must possess before learning the more advanced material (Hiebert & Carpenter, 1992; Rittle-Johnson et al., 2015). This is similarly explained by Al-Mutawah et al., (2019) and Ningrum et al., (2022), that if students have a good grasp of concepts, they will be able to solve problems. According to the Ministry of Primary and Secondary Education, mathematical conceptual understanding is one of mathematical abilities to indicate the achievement of the mathematics education goals (Kemendikdasmen, 2025). Therefore, mathematical conceptual understanding needs to be improved and is an ability that each individual must have.

In line with the previously mentioned goal of mathematics education, conceptual understanding is defined as the ability to discover, comprehend, restate, and apply concepts in daily life (Chen et al., 2023; Khairunnisa & Darhim, 2019; Ningrum et al., 2022). Another view defines concept understanding as the ability of students to explain, elaborate, convey, apply ideas to examples, and connect concepts with one another (Ncube & Luneta, 2025; Rupnow & Fukawa-Connelly, 2023). Conceptual understanding is the most critical aspect as it forms the basis for mastering other mathematical abilities (Setiani et al., 2022). Consequently, students should have a strong understanding of mathematical concepts.

A student is considered to have a good understanding of concepts if they have mastered all indicators of achievement for mathematical conceptual understanding. However, the level of mathematical conceptual understanding is still considered low. The previous studies revealed that student's mathematical conceptual understanding remains low (Alani & Wahyudin, 2022; Giawa et al., 2022; Khairi & Al Aziz, 2025; Kholid et al., 2021; May, 2023). Research conducted by Purwaningsih and Marlina (2022) found that the indicator most frequently mastered by students was "developing the necessary or sufficient conditions of a concept," out of seven indicators tested. This is because students have a poor understanding of the elements and operations of algebraic forms, making them less capable of solving algebraic problems presented in various formats.

The low level of mathematical conceptual understanding among students is also evident at one public junior high school in the city by giving them eight essay questions, with each question representing one indicator of conceptual understanding. The test was given to 148 students across five of the nine classes. The test covered material that the students had already studied, namely algebraic forms. The results of the diagnostic test showed that most students experienced difficulties in several indicators of conceptual understanding, including applying concepts logically, relating mathematical concepts, and developing necessary or sufficient conditions of a concept. These findings indicate that students still struggle to understand mathematical concepts deeply, particularly when solving problems presented in different representations. This condition suggests the need for learning approaches that actively involve students in discovering mathematical concepts.

According to previous research, students' suboptimal mastery of mathematical concepts results in them being unable to master the material well, meaning that mathematics learning outcomes are not achieved (Yanti & Fauzan, 2021). Furthermore, based on interviews with students during the learning process, they stated that the unavailability of adequate learning materials, that aligned with their school lessons, makes it difficult for them to understand the concepts being studied. Meanwhile, based on observations with a mathematics teacher, it was found that the school has already implemented the *Kurikulum Merdeka* (Emancipated Curriculum) in every level. However, the classroom learning process often uses direct instruction. The low mathematical conceptual understanding is also caused by students' low interest in learning, which leads to them not being actively involved in the lesson. During learning activities, students are not accustomed to discovering mathematical concepts themselves. This is reinforced by further interviews with students, which revealed that the lack of media appropriate to their characteristics is another cause of their low concept understanding. Additionally, during the learning process, teacher has tried to actively involve students in understanding concepts, but some students remain passive and do not respond to the teacher's questions (Vygotsky & Cole, 1978).

The teacher has explained the material well, but some students still not pay attention and were busy with their own activities. Consequently, when asked if there is anything they do not understand, some students choose to remain silent while others ask their friends. When given practice exercises, some students work independently, while others copy, even though the problems given by the teacher are similar to the examples. However, the reality is that many still cannot solve the problems and choose to work with their friends. As a result, the teacher directs them to work on the exercises in groups, and the students appear enthusiastic because they can help each other to solve the problems. This is also stated in research by Konstantinidou and Kyriakides (2022), which found that students' mathematical conceptual understanding is still low, caused by teaching methods that do not sufficiently develop learning models for the material being delivered, leading to student boredom.

Therefore, an effort is needed to improve students' mathematical conceptual understanding, because if this problem is left unaddressed, it is feared that students will lack a continuous mathematical conceptual understanding. Students will also fail to understand the material and will be unable to solve the given problems, meaning the objectives of mathematics education will not be achieved (Sampanis, 2020; Sulastri, 2019). Furthermore, it becomes an obstacle to developing other mathematical abilities. For that reason, an effort is required to overcome the problem of low mathematical conceptual understanding.

One solution to address low mathematical conceptual understanding is for teachers to apply a learning model that creates activities designed to train this skill. The learning model predicted to be suitable for this problem is the Discovery Learning model (Bruner, 1961). This is supported by research conducted by Alfieri et al. (2011) and Mayer (2004), which shows that the application of the Discovery Learning model can improve students' mathematical conceptual understanding. Ellizar et al., (2018) state that the Discovery Learning model can drive student’s activeness in constructing their own knowledge.

Previous studies also support the use of Discovery Learning in mathematics classrooms. Aziz and Subanti (2017) found that Discovery Learning can actively involve students in constructing knowledge, discovering principles and concepts, and improving learning achievement compared with classical learning. Similarly, Kristiyajati and Wijaya (2019) emphasised that Discovery Learning changes learning from teacher-centred instruction to student-oriented learning, where students identify information, organise ideas, and construct conceptual understanding under teacher guidance.

This solution is considered effective because it aligns with the facts found in the field. Based on the facts discovered during observation, applying the Discovery Learning model can involve students in groups by assigning group work according to their preferences (Ames, 2016; Helda et al., 2025; Yerizon et al., 2018). Students are also interested in being directly involved in discovering concepts for themselves, which can create an enjoyable learning environment (Stoffová, 2020). Moreover, by applying Discovery Learning, students can become more courageous in expressing their opinions within their groups and can ask peers for help without feeling shy and more confident (Balazinec et al., 2024; Helda et al., 2025).

Additionally, the implementation of Discovery Learning will be assisted by eXeLearning, an e-module that can combine several features (Means et al., 2013). This is supported by research from Novita et al., (2024), which shows that the use of learning media in the classroom is effective in improving students' mathematical conceptual understanding. This electronic module is designed using the eXeLearning XHTML editor, which is a free (open-source) application that can be used to create web-based teaching materials (Llerena-Izquierdo et al., 2025).

The eXeLearning application was chosen as the medium for implementing the Discovery Learning model because of its user-friendly and attractive interface, which is expected to arouse students' interest and enthusiasm for the learning material (My et al., 2026). This is also supported by research from Pratiwi et al., (2021), which indicates a significant influence on mathematical conceptual understanding when assisted by innovative and creative media, due to the active involvement of students during the learning process. The use of eXeLearning is not applied at every stage of the Discovery Learning model.

Based on the background described above, this research discusses the development of mathematical conceptual understanding. In addition, it analyses whether the mathematical conceptual understanding of students taught using the Discovery Learning model assisted by eXeLearning is better than that of students taught using a conventional learning model in the eighth grade at one public junior high school in a city.

Methods

Design

This type of research is descriptive and quasi-experimental, because it is not possible to control all relevant variables (Krishnan, 2019). Descriptive research aims to describe the development of mathematical conceptual understanding during the implementation of the Discovery Learning model assisted by eXeLearning. Meanwhile, quasi-experiments aim to determine whether the mathematical concept understanding of students whose learning uses the Discovery Learning model assisted by eXeLearning is better than that of students who use conventional learning models.

The research design used was a non-equivalent post-test only control group design. Research design of non-equivalent post-test only control group design is provided in Table 1 below.

Table 1
Research Design

Group	Treatment	Post-test
E	X	P
C	-	P

Descriptions:
E : Experiment Class
C : Control Class
X : Treatment using Discovery Learning Model Using eXeLearning
- : Treatment using Conventional Learning Model
P : Post-test Mathematical Conceptual Understanding

Sample and Population

The population in this study is all eighth-grade students at one junior high school in a city, consist of nine classes. The sample is selected using simple random sampling to ensure it was representative of the overall characteristics of the population. Thus, class VIII.1 was selected as the experimental class and given treatment using the Discovery Learning model assisted by eXeLearning, while class VIII.3 was selected as the control class and given treatment using the conventional learning model.

The research variables consist of independent variables, namely the Discovery Learning model assisted by eXeLearning in the experimental class and the conventional learning model in the control class. The dependent variable is the student's mathematical conceptual understanding. The type of data used is primary data in the form of scores from quizzes and post tests on mathematical conceptual understanding in the experimental and control classes, sourced from the students. Furthermore, secondary data consists of the number of students and mid-semester summative scores for Grade VIII sourced from the school administration and teachers.

Research Instruments

Quizzes and final tests on the topic of circle are research instruments to assess students' mathematical conceptual understanding. We designed quizzes based on the indicators of mathematical conceptual understanding and the learning objectives for each meeting. These quizzes were administered at least three times throughout the learning process to monitor students' development across different indicators. Each quiz measured different aspects of conceptual understanding, allowing the researcher to observe students' progress in a structured and continuous manner. The final test of mathematical conceptual understanding was administered in the form of essay questions. This format was chosen to allow a deeper analysis of students' conceptual understanding through the explanations provided in their answers. The test items were constructed based on established indicators of mathematical conceptual understanding. Prior to implementation, the test was evaluated to ensure its validity and reliability, indicating that it was appropriate for measuring students' conceptual understanding accurately. Indicators research instrument is displayed in Tabel 2 below.

Table 1
Instrument Blueprint

Indicator of Conceptual Understanding	Item Number
Restate a concept.	1
Classify objects based on whether they meet the requirements of the concept.	2
Identify the properties of operations or concepts.	3
Apply concepts logically.	4
Provide examples and counterexamples (not examples) of the concept being studied.	5
Present concepts in mathematical representations (tables, graphs, diagrams, mathematical models, or other means).	6

Relating various concepts within mathematics and outside of mathematics.	7
Developing necessary and/or sufficient conditions for a concept.	8

Research Procedure

In the preparation stage, several activities were conducted to ensure the readiness of the research. First, the research site and schedule were determined. The study was conducted at one junior public junior high school in a city. Next, permission to conduct the research was obtained from the relevant authorities. The researcher then determined the sample classes, where one class was assigned as the experimental class and another as the control class. Furthermore, the learning materials for Grade VIII were analysed based on the expected learning objectives. The researcher also prepared instructional tools, including lesson plans, student worksheets, quizzes, and learning media using eXeLearning. In addition, research instruments were developed, consisting of a test blueprint, trial test items for mathematical conceptual understanding, and answer keys. All instructional tools and research instruments were validated by two experts in mathematics education to ensure their validity and feasibility. Based on the feedback from the validators, necessary revisions were made to improve the quality of the instruments and learning materials.

In the implementation stage, the learning process was carried out according to the prepared plan. The experimental class was taught using the Discovery Learning model assisted by eXeLearning, while the control class received conventional instruction. Before administering the final test, a trial test was conducted in a different class with similar characteristics to evaluate the quality of the test items. Afterward, the learning activities were implemented in both classes based on their respective instructional approaches.

In the completion stage, several final activities were conducted. First, the results of the trial test were analysed to determine the validity and reliability of the test items. Then, a post-test on mathematical conceptual understanding was administered to both the experimental and control classes based on the material that had been taught. The collected data were then processed and analysed using appropriate statistical techniques. Finally, conclusions were drawn based on the results of the data analysis conducted in this study.

Data Analysis

The quiz data analysis was based on the scoring of students' mathematical conceptual understanding. The obtained scores were then converted into a scale ranging from 0 to 100, to provide a clearer interpretation of students' performance. This conversion aimed to present a more comprehensive picture of the development of students' conceptual understanding over time. Students' conceptual understanding was considered to have developed if it reached at least the "good" or "very good" category based on the predetermined criteria.

The final test data analysis of mathematical conceptual understanding began with calculating students' scores, which were also converted into a 0–100 scale. All data analyses were conducted using Minitab. The analysis proceeded with a normality test using the Anderson–Darling test, which indicated that the data were normally distributed. After confirming normality, a homogeneity of variance test was conducted using the F-test, which showed that the variances between the sample groups were not homogeneous. Therefore, hypothesis testing was carried out using an independent samples t-test. The results revealed that the average post-test score of students' mathematical conceptual understanding in the class taught using Discovery Learning assisted by eXeLearning was higher than that of students taught using conventional learning methods.

Results and Discussion

Results

This chapter presents the results of research obtained from the effect of the application of the Discovery Learning model assisted by eXeLearning on the mathematical conceptual understanding of students in the experimental class, which was compared with the mathematical conceptual understanding of students who followed conventional learning models in the control class. Additionally, it explains how the development of mathematical conceptual understanding of students using the Discovery Learning model assisted by eXeLearning in the eighth grade of one junior high school at the city.

The Development of Students' Mathematical Conceptual Understanding

The development of students' mathematical conceptual understanding among eighth-grade students at one junior high school in the city can be seen from the average quiz scores for each meeting, as shown in Table 3 below.

Table 3
Average Quiz Scores of Students in Each Meeting

Quiz	Average	Category
I	82.49	Excellent
II	64.84	Good
III	85.79	Excellent
IV	90.85	Excellent
V	94.69	Excellent
VI	90.33	Excellent

Based on Table 3, the average quiz scores of students for most meetings were increasing, except for the second and sixth quiz. Thus, based on the category of average quiz scores of students being very good, it can be said that students' mathematical conceptual understanding has improved.

The improvement in students' mathematical conceptual understanding was observed through a comparison of the average scores for each indicator for each quiz. The average quiz scores for students' mathematical conceptual understanding based on the mathematical conceptual understanding indicators presented in Table 4 below.

Table 4
Average Quiz Scores of Students in the Experimental Class for Each Indicator

Indicator	Max Score	Quiz					
		I	II	III	IV	V	VI
1	2	1.19	-	1.78	-	-	1.93
2	2	1.55	-	1.91	1.94	-	-
3	4	3.3	-	3.69	-	3.84	-
4	4	-	2.88	3.41	3.72	3.75	-
5	4	3.8	-	3.56	-	-	3.63
6	4	-	2.78	2.88	3.63		-
7	4	-	2.31	-	3.41	-	3.47
8	2	1.7	-	1.66	-	1.88	-

From Table 4, each indicator experienced an increase except for indicators 5 and 8, which experienced a decrease in quiz III by 0.24 and 0.04, respectively. Therefore, based on the results of the average score for each indicator, it can be concluded that there was an improvement in students' mathematical conceptual understanding during the implementation of the Discovery Learning model assisted by eXeLearning.

Based on the explanation of the average scores of students' mathematical conceptual understanding in each quiz, it can be concluded that, in general, the average scores of students have consistently improved. This means that, although there may have been variations in student performance at the beginning, over time their average quiz scores have increased significantly. This reflects positive progress in improving mathematical conceptual understanding. Every improvement demonstrates that students' mathematical conceptual understanding is enhancing, meaning that there has been development in mathematical conceptual understanding in the experimental class of eXeLearning.

Post-test of Students' Mathematical Conceptual Understanding

The comparison between the mathematical conceptual understanding of students in two classes class can be seen from the results of the mathematical conceptual understanding test that was administered. The test questions used were in essay form, consisting of eight questions. Each question contained one indicator of mathematical conceptual understanding. The test was conducted at the end of the study on February 15, 2025 for the experimental class, and on February 14, 2025 for the control class. The number of students participating in the experimental and control class were 32 and 30, respectively. The test results data can be seen in Table 5 below.

Table 5
Results of Mathematical Concept Comprehension Tests for Sample Classes

Group	Number of Participant	Average	Standard Deviation	Max Score	Min Score

Experiment	32	73.32	9.77	88	55
Control	30	50.64	21.40	81	15

Table 5 shows that the average test scores of the experimental class are higher than those of the control class. The average test score of the experimental class is 73.32, while that of the control class is 50.64. The highest score in the experimental class is also higher than that of the control class. The highest score in the experimental class is 88, while that of the control class is 81. The lowest score in the experimental class is also higher than that of the control class, with the lowest scores of 55 for the experimental class and 15 for the control class. The standard deviation of the control class is higher than that of the experimental class. The standard deviation of the control class is 21.40, and the standard deviation of the experimental class is 9.77. This indicates that the mathematical conceptual understanding of the control class students is more diverse than that of the experimental class.

This study was conducted to test the hypothesis regarding the effect of implementing the eXeLearning-assisted Discovery Learning model on students' mathematical conceptual understanding. The research hypothesis is that there is a significant effect of this model, such that students who learn using the eXeLearning-assisted Discovery Learning model will demonstrate a better mathematical conceptual understanding compared to students who learn using a conventional model. The subjects of this study were eighth-grade students at one junior high school in the city. Before performing the hypothesis test, preliminary analyses, including a normality test and a test for homogeneity of variances, were carried out using Minitab software can be seen in Figure 1 and Figure 2 below.

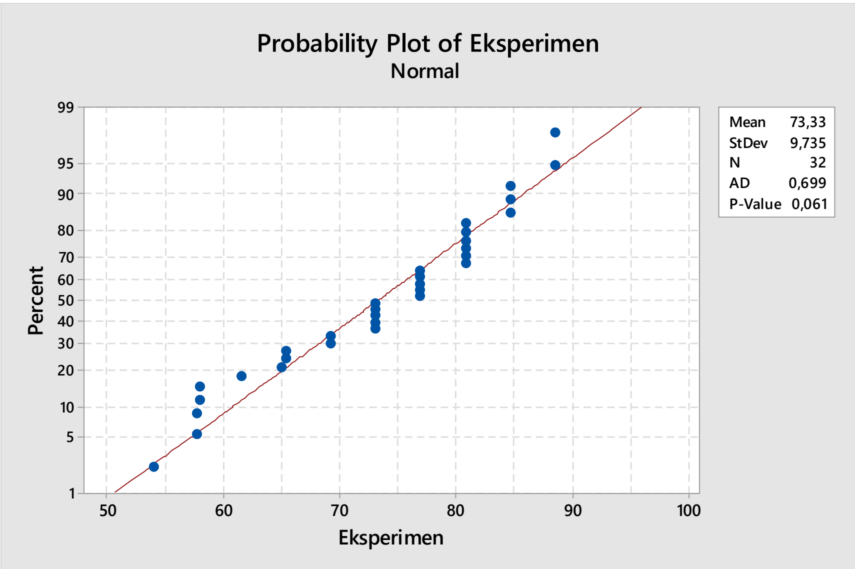

Figure 1. Probability plot of experiment class.

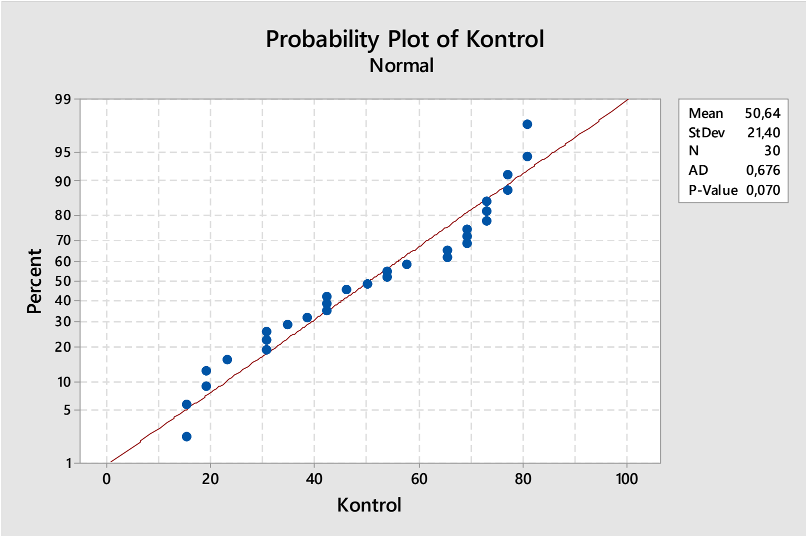

Figure 2. Probability plot of control class.

Based on Figure 1 and Figure 2, the normality test aims to determine whether the data is normally distributed. The normality test on the data from the students' final test of mathematical conceptual understanding was conducted using the Anderson-Darling test. Based on the normality test performed, the P-Value for the experimental class was 0.061, and for the control class it was 0.070. This means that because the P-Value for both classes is $> \alpha$ and it can be concluded that the sample classes are normally distributed.

After performing the data normality test, the next step is the homogeneity of variance test, which aims to determine whether the two sample classes have homogeneous variance or not. The homogeneity of variance test uses the F-test. The result shown in Table 6 below.

Table 6

The Results of the Homogeneity of Variance Test Using the F-test

Method	Test Statistic	DF1	DF2	P-Value
F	0.21	31	29	0.000

According to the test for homogeneity of variances presented in Table 6, the P-Value is 0.000. Because the P-Value $< \alpha$, it is concluded that the variances of the two sample classes are not homogeneous.

Following the normality and homogeneity tests were conduct, the research hypothesis test was then carried out. The test aimed to determine whether the mathematical conceptual understanding of eighth-grade students at one junior high school in the city, whose learning implemented the eXeLearning-assisted Discovery Learning model, was better than that of students who used a conventional learning model. Based on the normality and homogeneity of variance tests, the data was found to be normally distributed, but the variances were not homogeneous. Therefore, the research hypothesis was tested using the t-test. The results of the research hypothesis test calculations can be seen in Table 7 below.

Table 7

The Result of Hypothesis Test Using t-test

T-Value	DF	P-Value
5.31	39	0.000

Based on Table 7 above, the P-Value is 0.000. Therefore, it can be concluded that the average post-test score for mathematical conceptual understanding of eighth-grade students at one junior high school in the city, who were taught using the eXeLearning-assisted Discovery Learning model, is better than that of students taught using the conventional learning model.

After the hypothesis test was conducted, each indicator of mathematical conceptual understanding from the experimental and control classes was then analysed. A comparison of the average scores for each indicator of mathematical conceptual understanding can be seen in the Table 8 below.

Table 8

Average Mathematical Conceptual Understanding Test Scores for Each Indicator in the Sample Classes

No	Indicator of Mathematical Conceptual Understanding	Average Score	
		Experiment	Control
1	Restate a concept.	1.84	1.43
2	Classify objects based on whether they meet the requirements of the concept.	1.41	1.37
3	Identify the properties of operations or concepts.	3.63	2.97
4	Apply concepts logically.	3.25	1.97
5	Provide examples and counterexamples (not examples) of the concept being studied.	2.97	2.03
6	Present concepts in mathematical representations (tables, graphs, diagrams, mathematical models, or other means).	2.44	1.63
7	Relating various concepts within mathematics and outside of mathematics.	1.94	1
8	Developing necessary and/or sufficient conditions for a concept.	1.59	0.77

Based on Table 8, the average mathematical conceptual understanding scores of students for the eight indicators in the experimental class eXeLearning were higher than those of students in the control class, whose learning was conducted using the conventional learning model. Thus, it can be concluded that the mathematical conceptual understanding of students in the experimental class was better than that of students in the control class. This fact supports the validity of the hypothesis test results that the mathematical conceptual understanding of students who learn using the Discovery Learning model assisted by eXeLearning is better than the mathematical conceptual understanding of students who learn using the conventional learning model in grade VIII at one junior high school in the city.

Discovery Learning Assisted by eXeLearning

The findings of this study demonstrate that students who were taught using Discovery Learning assisted by eXeLearning achieved higher mathematical conceptual understanding compared to those who experienced conventional instruction. This result supports the constructivist learning theory, which posits that knowledge is actively constructed by learners through meaningful engagement with learning experiences. Discovery Learning facilitates this process by encouraging students to explore, investigate, and derive conclusions independently, thereby promoting deeper cognitive processing. This finding is consistent with previous studies indicating that Discovery Learning enhances students' conceptual understanding by fostering active learning and critical thinking (Alfieri et al., 2011; Mayer, 2004). Through guided discovery, students are not only exposed to mathematical procedures but are also encouraged to understand the underlying concepts, which leads to more meaningful learning outcomes.

Furthermore, the integration of eXeLearning as a digital learning medium plays a significant role in supporting the effectiveness of Discovery Learning. Digital platforms, one of which is eXeLearning, provide interactive and structured learning environments that allow students to visualize abstract mathematical concepts, access learning materials flexibly, and engage in self-paced exploration (Llerena-Izquierdo et al., 2025). This aligns with the findings of previous research, which suggest that technology-enhanced learning environments can improve students' conceptual understanding by providing multiple representations and interactive learning experiences (Clark & Mayer, 2023). The progressive improvement observed in students' quiz results throughout the learning process further indicates that the combination of Discovery Learning and eXeLearning supports continuous conceptual development. This suggests that learning is not only influenced by instructional models, but also by the availability of tools that facilitate independent and meaningful learning experiences. Therefore, the integration of pedagogical approaches, such as Discovery Learning with digital learning media, creates a more effective learning environment that supports students in constructing and strengthening their mathematical conceptual understanding.

The Development of Students' Mathematical Conceptual Understanding

The development of students' mathematical conceptual understanding fluctuated during the implementation of the Discovery Learning model assisted by eXeLearning. There were both increases and decreases in the average score per indicator. The improvement in mathematical conceptual understanding occurred as students became more accustomed to the learning model being used. The mathematical conceptual understanding problems given also became more familiar to them. This is in line with the opinion of Maifi et al., (2021), who stated that the application of the Discovery Learning model can improve students' mathematical conceptual understanding. Furthermore, it aligns with the research results of Sa'diyah et al., (2024), which found that this indicator showed an increase when comparing the results before and after the treatment was administered.

A decrease in quiz scores was also found for indicator 5 and indicator 8 on Quiz III. This was because the third quiz had more questions than the others, which required more time to complete. This is in line with the opinion of Izienicki (2024), who stated that a decrease in quiz scores indicates a greater challenge or a lack of understanding of the related material. Furthermore, another cause for the drop in quiz scores was the students' difficulty in understanding complex material, which in turn affected their learning outcomes. This is supported by the research of Biya et al., (2023), which found that more complex material can cause students to have difficulty with comprehension and can impact their quiz results.

Based on the previous discussion, it can be concluded that, in general, students' mathematical conceptual understanding developed during the implementation of the Discovery Learning model assisted by eXeLearning. This can be seen from the influence of this model in the learning process. The Discovery Learning model makes students more active, so they do not just passively receive knowledge from the teacher, but are also required to discover concepts for themselves by discussing with groupmates under the teacher's guidance (Hoerudin, 2023; Rosa et al., 2025).

In the Discovery Learning assisted by eXeLearning, students can gain an in-depth understanding of the material by working collaboratively in their heterogeneously abled groups to complete the provided student worksheets. This is in line with the research by Purwaningsih et al., (2019) and Sun and Cheng (2007), who stated that the presence of media is essential for achieving learning objectives. In addition to selecting media that can enhance mathematical abilities, teachers must also choose a suitable model that can stimulate student activeness in the learning process. Such activities can influence students' mathematical conceptual understanding because they discover the concepts themselves (Bishara, 2021).

Post-test Students' Mathematical Conceptual Understanding

Initially, the students in both classes were considered to have the same initial ability, as indicated by the results of the test for equality of means. This shows that there was no significant difference between the two groups in terms of their initial mathematical conceptual understanding. The experimental class received the Discovery Learning model assisted by eXeLearning treatment, while the control class was taught using a conventional learning model.

Based on the research findings, the average score of the students in the experimental class was higher than that of the students in the control class. Furthermore, the hypothesis test also indicated that the mathematical conceptual understanding of the students in the experimental class was better than that of the control class. This occurred because the students in the experimental class used the Discovery Learning model assisted by eXeLearning during the learning process. This is in line with the research by Helda et al., (2025), Rosa et al., (2025), and Stoffová (2020), that the application of Discovery Learning encourages students to be actively involved in learning. Moreover, students who learn using Discovery Learning gain a deeper mathematical conceptual understanding, so they not only memorize formulas but also understand how to derive them. Research by Hoerudin, (2023) and Rosa et al., (2025) show that the use of digital media has a positive influence on improving mathematical conceptual understanding, partly by making students more active in discovering concepts. In addition, research by Rohmadi et al., (2022) shows that using eXeLearning is effective in helping students better understand concepts and increasing their learning motivation. In addition, Sawah (2022) showed that a discovery-based TUAM approach could improve students' mathematical thinking processes more effectively than a more teacher-directed approach.

The Discovery Learning model assisted by eXeLearning carried out in several stages. The Discovery Learning stage begins by presenting a problem to stimulate the students (stimulation), thus arousing their curiosity. This activity greatly influences students' mathematical conceptual understanding of the material being studied because they discover the concepts themselves through questions on the student worksheets and guiding questions from the teacher, allowing them to propose preliminary hypotheses during the problem statement stage.

After forming preliminary hypotheses, students need information to verify their guesses, so they proceed to collect the necessary data (data collecting). At this stage, students are required to use the eXeLearning media as directed by the teacher. This allows students to gather more complete information about the material. Additionally, the eXeLearning media is used to help students discover concepts on the topic of circles based on questions in the worksheet and prompts from the teacher. One of the data collection processes for the material on finding the value of pi and the circumference of a circle is a feature that students can use on a computer or mobile phone at home. The web display can be seen in Figure 3 below.

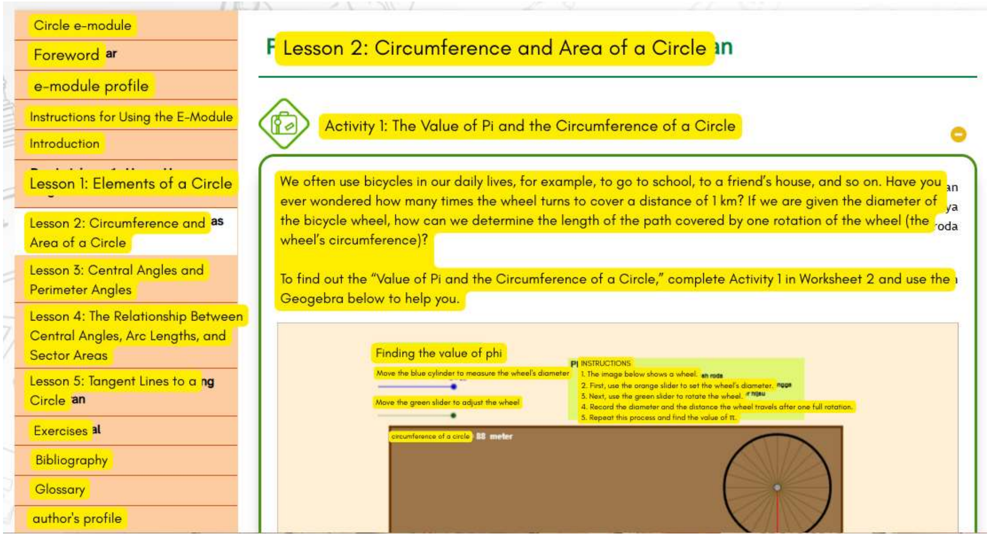

Figure 3. The eXeLearning display in the second meeting discusses the process of finding the value of phi and the circumference of a circle.

eXeLearning is demonstrated by the teacher, and students are randomly asked to use it at the front of the class. Using eXeLearning makes the students' experience more meaningful, and by obtaining information, they gain more insight to provide complete and correct reasoning for the validity of their solutions. This is supported by the opinion of Druckman and Ebner (2018), who noted that the active participation of each student is very evident. When students encounter difficulties, they actively discuss with their groups and ask the teacher. Furthermore, research by Llerena-Izquierdo et al., (2025) shows that using an eXeLearning e-module provides flexibility in adapting content as learning progresses because it can be accessed at school, at home, or anywhere via the students' mobile phones. Through this technology, teachers can realize progressive learning while encouraging and inspiring students to achieve optimal learning outcomes.

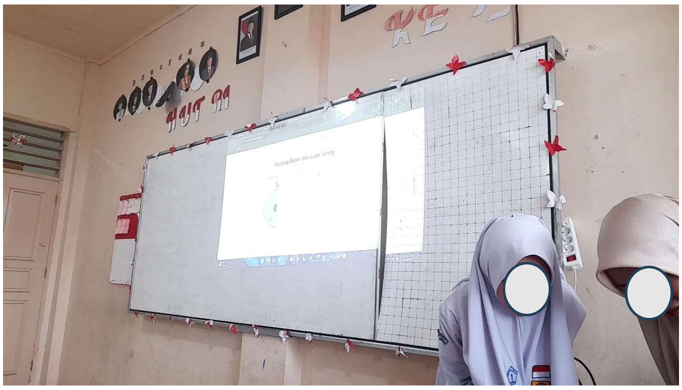

Figure 4. The students were guided by the teacher in using eXeLearning to collect data.

After students obtained the necessary information, they processed the data (data processing) to verify the hypotheses they proposed. This involves several steps, such as processing the data collected from the previous stage and answering questions in the worksheet. The teacher walked around the classroom to assist any students who did not understand a question. By engaging in this activity, students would remember the required steps for a longer period and became more creative in solving problems. By becoming accustomed to these activities, students would more easily and habitually find patterns to solve a problem. This is in line with research by Stoffová (2020), Tokada et al., (2017), and Wada et al., (2019), which shows that through Discovery Learning, teacher involve students in actively discovering knowledge on their own. With Discovery Learning, students think analytically and try to solve problems themselves, which impacts their proficiency in solving mathematical problems and leads to longer retention of the material.

After finding a solution, students proceed to the verification stage to determine if their answer was correct. The teacher verifying the students' findings after they have been discussed. Other students were asked to respond to the presented results. After confirming the correctness of their solution, students drew a conclusion or made a generalization from the problem they have faced. By having students conclude the material themselves, they will remember it for a longer time. This is consistent with the research by Karan (2023), which shows that students remember information longer because they gain direct learning experiences, making the learning process more meaningful.

Based on all the data analysis results, it is proven that the Discovery Learning model assisted by eXeLearning influences students' mathematical conceptual understanding. The results of the hypothesis testing in this study conclude that the average mathematical conceptual understanding of eighth-grade students at one junior high school in the city who learned using the Discovery Learning model assisted by eXeLearning is better than that of students who learned with the conventional learning model. This is supported by the research of Rosa et al., (2025), which showed a significant difference in students' mathematical conceptual understanding between those using the Discovery Learning model and the direct instruction model.

In the control class, the conventional learning model applied was the direct instruction model. In this model, the teacher directly teaches the material and demonstrates the knowledge needed to solve problems. However, in practice, students were only able to solve problems identical to those demonstrated by the teacher. If students were presented with a related problem in a different format, they had difficulty solving it. In contrast, students in the experimental class were regularly exposed to conceptual understanding problems through quizzes.

The results of this study are consistent with the research by Anggraini et al., (2018), which found that the conceptual understanding of students taught with the Discovery Learning model was better than that of those taught with conventional learning. The same was also found by Maifi et al., (2021), whose research showed that the mathematical conceptual understanding of students using the Discovery Learning model was superior to that of students using conventional learning. One contributing factor was the lack of learning media, which resulted in students tending to be more passive.

Conclusion

The development of students' mathematical conceptual understanding during the implementation of the Discovery Learning model assisted by eXeLearning, showed gradual improvement from one quiz to the next. This indicates that the implementation of the Discovery Learning model assisted by eXeLearning can help students become accustomed to discovering the concepts they are learning on their own. The results of this study indicate that the implementation of Discovery Learning assisted by eXeLearning contributes to the improvement of students' mathematical conceptual understanding.

Students who participated in this learning approach demonstrated better conceptual understanding compared to those who experienced conventional instruction. The integration of digital learning media provides opportunities for students to actively construct knowledge, explore concepts, and develop independent learning skills. Therefore, this approach can be considered an effective instructional strategy in mathematics learning. However, these findings are limited to the context of this study and should be interpreted with caution when generalized to other educational settings.

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References

Al-Mutawah, M. A., Thomas, R., Eid, A., Mahmoud, E. Y., & Fateel, M. J. (2019). Conceptual understanding, procedural knowledge and problem-solving skills in mathematics: High school graduates work analysis and standpoints. *International Journal of Education and Practice*, *7*(3), 258 – 273. https://doi.org/10.18488/journal.61.2019.73.258.273

Alani, N., & Wahyudin. (2022). Students' Mathematical Conceptual Understanding during Online Learning. *AIP Conference Proceedings*, *2468*. https://doi.org/10.1063/5.0102776

Alfieri, L., Brooks, P. J., Aldrich, N. J., & Tenenbaum, H. R. (2011). Does discovery-based instruction enhance learning? *Journal of Educational Psychology*, *103*(1), 1-18. https://doi.org/10.1037/a0021017

Ames, K. (2016). Distance Education and 'Discovery Learning' in First-year Journalism: A Case in Subject Improvement. *Asia Pacific Media Educator*, *26*(2), 214 – 225. https://doi.org/10.1177/1326365X16669196

Anggraini, R. D., Murni, A., & Sakur. (2018). Differences in students' learning outcomes between discovery learning and conventional learning models. *Journal of Physics: Conference Series*, *1088*. https://doi.org/10.1088/1742-6596/1088/1/012070

Aziz, A., & Subanti, S. (2017). The Effect of Inquiry Learning and Discovery Learning on Student Learning Achievement Viewed from Spatial Intelligence. In *Southeast Asian Mathematics Education Journal* (Vol. 7, Issue 2).

Balazinec, M., Radanovic, I., & Bulic, M. (2024). Self-Regulated Learning in Science Classes with a Discovery Learning Environment and Collaborative Discovery Learning Environment. *Education Sciences*, *14*(6). https://doi.org/10.3390/educsci14060669

Bishara, S. (2021). The cultivation of self-directed learning in teaching mathematics. *World Journal on Educational Technology: Current Issues*, *13*(1), 82 – 95. https://doi.org/10.18844/wjet.v13i1.5401

Biya, S. A., Isa, I., & Lukman A.R. Laliyo. (2023). Pengaruh Model Pembelajaran Discovery Learning Terhadap Pemahaman Konsep Pada Materi Termokimia di SMA Negeri 1 Mananggu [The Effect of the Discovery Learning Model on Conceptual Understanding of Thermochemistry at Mananggu State High School 1]. *Jurnal Pendidikan Kimia Undiksha*, *7*(1), 23–28. https://doi.org/10.23887/jjpk.v7i1.59726

Bruner, J. S. (1961). *The act of discovery*. *Harvard Educational Review*.

Chen, Y., Rao, A., Xu, Z., Zhang, C., & Guan, H. (2023). Study of Raising Students Level of Geometric Understanding with the Aid of Technology. *ACM International Conference Proceeding Series*, 153 – 158. https://doi.org/10.1145/3625704.3625777

Clark, R. C., & Mayer, R. E. (2023). *E-learning and the science of instruction: Proven guidelines for consumers and designers of multimedia learning*. john Wiley \& sons.

Druckman, D., & Ebner, N. (2018). Discovery Learning in Management Education: Design and Case Analysis. *Journal of Management Education*, *42*(3), 347 – 374. https://doi.org/10.1177/1052562917720710

Ellizar, E., Hardeli, H., Beltris, S., & Suharni, R. (2018). Development of Scientific Approach Based on Discovery Learning Module. *IOP Conference Series: Materials Science and Engineering*, *335*(1). https://doi.org/10.1088/1757-899X/335/1/012101

Giawa, L., Gee, E., & Harefa, D. (2022). Analisis Kemampuan Pemahaman Konsep Matematis Pada Materi Bentuk Pangkat dan Akar di Kelas XI SMA Negeri 1 Ulusua Tahun Pembelajaran 2021/2022 [Analysis of Mathematical Concept Comprehension in the Topic of Exponents and Roots in Grade 11 at Ulusua State . *AFORE: Jurnal Pendidikan*

Matematika, *1*(1).

Helda, T., Indriyani, V., Yusandra, T. F., Marni, S., & Upit Yulianti, D. N. (2025). Shaping Communicative Identity Through Group-Discovery Learning Model: Enhancing 21st Century Skills in Language Education; [Membentuk Identitas Komunikatif Melalui Model Pembelajaran Penemuan Kelompok: Meningkatkan Keterampilan Abad ke-21 dalam Pendidikan Bahasa]. *Jurnal Gramatika*, *11*(1), 155 – 170. https://doi.org/10.22202/jg.v11i1.9584

Hiebert, J., & Carpenter, T. P. (1992). Learning and teaching with understanding. In D. A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning* (pp. 65–97). Macmillan.

Hoerudin, C. W. (2023). Indonesian Language Learning Using the Discovery Learning Model Based on High Order Thinking Skills (HOTS) on Students' Analytical Thinking Ability. *Munaddhomah*, *4*(1), 122 – 131. https://doi.org/10.31538/munaddhomah.v4i1.370

Izienicki, H. (2024). Beyond Policies and Procedures: Using the Syllabus Quiz to Predict How Well Students Will Perform in a College Course. *Teaching Sociology*, *52*(3), 248 – 256. https://doi.org/10.1177/0092055X231196173

Karan, E. (2023). Discovery-Based Approach Combined with Active Learning to Improve Student Learning Experiences for STEM Students. *Journal of Education and Training Studies*, *11*(4), 16 – 25. https://doi.org/10.11114/jets.v11i4.6205

Kemendikdasmen. (2025). *Keputusan Kepada Badan Standar, Kurikulum, dan Asesmen Pendidikan Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi Nomor 046/H/KR/2025 Tentang Capaian Pembelajaran Pada Pendidikan Anak Usia Dini, Jenjang Pendidikan Dasar, dan Jenjang Pendidikan Menengah [Decision of the Agency for Educational Standards, Curriculum, and Assessment of the Ministry of Education, Culture, Research, and Technology No. 046/H/KR/2025 Regarding Learning Outcomes in Early Childhood Education, Primary Education, and Secondary Education]*. Kementerian Pendidikan Dasar dan Menengah.

Khairi, A. U., & Al Aziz, S. (2025). Analisis Pemahaman Konsep Matematis Siswa Pada Materi Bentuk Aljabar [Analysis of Students' Understanding of Mathematical Concepts in Algebraic Expressions]. *Didactical Mathematics*, *7*(1), 95–104.

Khairunnisa, & Darhim. (2019). Analysis of students' conceptual and procedural understanding of linear programming. *Journal of Physics: Conference Series*, *1280*(4). https://doi.org/10.1088/1742-6596/1280/4/042018

Kholid, M. N., Imawati, A., Swastika, A., Maharani, S., & Pradana, L. N. (2021). How are Students' Conceptual Understanding for Solving Mathematical Problem? *Journal of Physics: Conference Series*, *1776*(1). https://doi.org/10.1088/1742-6596/1776/1/012018

Konstantinidou, E., & Kyriakides, L. (2022). Instructional engagement and student learning outcomes: Direct and indirect effects based on country-specific contingencies. *Studies in Educational Evaluation*, *73*. https://doi.org/10.1016/j.stueduc.2022.101144

Krishnan, P. (2019). A review of the non-equivalent control group post-test-only design. *Nurse Researcher*, *26*(2), 37 – 40. https://doi.org/10.7748/nr.2018.e1582

Kristiyajati, A., & Wijaya, A. (2019). The Effectiveness of Visualization of Proofs in Learning Mathematics by Using Discovery Learning Viewed from Conceptual Understanding. In *Southeast Asian Mathematics Education Jurnal* (Vol. 9, Issue 1).

Llerena-Izquierdo, J., Pombo-Bermeo, A., Pizarro-Vasquez, G., & Iniguez-Magallanes, H. (2025). Impact of eXeLearning on Interactive Educational Content in Secondary Education. *EDUNINE 2025 - 9th IEEE Engineering Education World Conference: Education in the Age of Generative AI: Embracing Digital Transformation - Proceedings*. https://doi.org/10.1109/EDUNINE62377.2025.10981368

Maifi, Y. K., Anwar, & Ahmad, A. (2021). Students' understanding of mathematical concepts and their self-confidence through a discovery learning model. *Journal of Physics: Conference Series*, *1882*(1). https://doi.org/10.1088/1742-6596/1882/1/012081

May, B. M. (2023). Retrieval practice and test-potentiated learning: A comparison of high and low prior topic knowledge students in terms of procedural fluency and conceptual understanding. *Pythagoras*, *45*(1). https://doi.org/10.4102/PYTHAGORAS.V45I1.755

Mayer, R. E. (2004). Should there be a three-strikes rule against pure discovery learning? *American Psychologist*, *59*(1), 14-19. https://doi.org/10.1037/0003-066X.59.1.14

Means, B., Toyama, Y., Murphy, R., & Baki, M. (2013). The effectiveness of online and blended learning: A meta-analysis of the empirical literature. *Teachers College Record*, *115*(3), 1–47.

My, P. D., Yen, T. H., & Quynh, N. H. (2026). The Role of Emotional Experience in Student Engagement on E-Learning Platforms: An Extended Technology Acceptance Mode. *Lecture Notes in Networks and Systems*, *1581 LNNS*, 21 – 34. https://doi.org/10.1007/978-3-032-00972-2_2

Ncube, M., & Luneta, K. (2025). Concept-based instruction: Improving learner performance in mathematics through conceptual understanding. *Pythagoras*, *46*(1), 1 – 18. https://doi.org/10.4102/pythagoras.v46i1.815

Ningrum, D. P. N., Usodo, B., & Subanti, S. (2022). Students' Mathematical Conceptual Understanding: What Happens to Proficient Students? *AIP Conference Proceedings*, *2566*. https://doi.org/10.1063/5.0116651

Novita, R. R., Jumadi, & Damayanti, N. (2024). Analyzing students' conceptual understanding as a learning effect through Android based learning media with KWL strategy. *AIP Conference Proceedings*, *2622*(1). https://doi.org/10.1063/5.0133278

Pratiwi, D. D., Mujib, Andriani, S., Mardiyah, Kuswanto, C. W., & Utami, E. (2021). Application of algebraic tile media with gasing: Ability to understand mathematical concepts and student creativity. *IOP Conference Series: Earth and Environmental Science*, *1796*(1). https://doi.org/10.1088/1742-6596/1796/1/012023

Purwaningsih, E., Nurhadi, D., & Masjkur, K. (2019). TPACK development of prospective physics teachers to ease the achievement of learning objectives: A case study at the State University of Malang, Indonesia. *Journal of Physics: Conference Series*, *1185*(1). https://doi.org/10.1088/1742-6596/1185/1/012042

Purwaningsih, S. W., & Marlina, R. (2022). Analisis Kemampuan Pemahaman Konsep Matematis Siswa Kelas VII Pada Materi Bentuk Aljabar [Analysis of Seventh-Grade Students' Mathematical Concept Comprehension Skills in Algebraic Expressions]. *JPMI (Jurnal Pembelajaran Matematika Inovatif)*, *5*(3), 639–648. https://doi.org/10.22460/jpmi.v5i3.639-648

Rittle-Johnson, B., Schneider, M., & Star, J. R. (2015). Not a one-way street: Bidirectional relations between procedural and conceptual knowledge of mathematics. *Educational Psychology Review*, *27*(4), 587–597.

Rohmadi, M., Yuliani, H., Syar, N. I., Supriatin, A., Azizah, N., Perriy, P., & Dinawati, N. C. (2022). Pengenalan Media Pembelajaran Exe-Learning Terintegrasi Nilai Keislaman pada Pelajaran Fisika [Introduction to Exe-Learning Educational Media Integrating Islamic Values into Physics Lessons]. *SIPISSANGNGI: Jurnal Pengabdian Kepada Masyarakat*, *2*(2), 103. https://doi.org/10.35329/sipissangngi.v2i2.2775

Rosa, T. D. M., Aryani, I., Agustina, P., Astuti, R., & Mufanti, R. (2025). The Effectiveness of the Discovery Learning Model Using Schoology to Improve Class X Learning Outcomes of Muhammadiyah High School. *AIP Conference Proceedings*, *3142*(1). https://doi.org/10.1063/5.0262151

Rupnow, R., & Fukawa-Connelly, T. (2023). How mathematicians characterize and attempt to develop understanding of concepts and definitions in proof-based courses. *Frontiers in Education*, *8*. https://doi.org/10.3389/feduc.2023.1284666

Sa'diyah, P. H., Maulana, & Isrokatun. (2024). Peningkatan Pemahaman Konsep dengan Menggunakan Model Learning Cycle 7E Berbantuan Puzzle [Improving Conceptual Understanding Using the 7E Learning Cycle Model with Puzzles]. *Jurnal Elementaria Edukasia*, *7*(1), 2475–2489. https://doi.org/10.31949/jee.v7i1.8825

Sampanis, N. (2020). Transitioning Knowledge Levels Through Problem Solving Methods. *Advances in Experimental Medicine and Biology*, *1194*, 459 – 474. https://doi.org/10.1007/978-3-030-32622-7_45

Sawah, K. O. (2022). Vanuatu's Typical Approach of Mathematics vs the TUAM Approach of Mathematics. In *Southeast Asian Mathematics Education Journal* (Vol. 12, Issue 1).

Setiani, N., Roza, Y., & Maimunah. (2022). Analisis Kemampuan Siswa Dalam Pemahaman Konsep Matematis Materi Peluang Pada Siswa SMP [Analysis of Middle School Students' Ability to Understand Mathematical Concepts in Probability]. *Jurnal Cendekia : Jurnal Pendidikan Matematika*, *06*(02), 2286–2297.

Stoffová, V. (2020). Discovery learning by interactive animation models. *ELearning and Software for Education Conference*, 246 – 252. https://doi.org/10.12753/2066-026X-20-116

Sulastri, R. (2019). Difficulties of prospective teachers in solving mathematical problem: PISA on most difficult level. *Journal of Physics: Conference Series*, *1232*(1). https://doi.org/10.1088/1742-6596/1232/1/012036

Sun, P.-C., & Cheng, H. K. (2007). The design of instructional multimedia in e-Learning: A Media Richness Theory-based approach. *Computers and Education*, *49*(3), 662 – 676. https://doi.org/10.1016/j.compedu.2005.11.016

Tokada, D., Herman, T., & Suhendra. (2017). Discovery Learning for Mathematical Literacy Ability. *Journal of Physics: Conference Series*, *895*(1). https://doi.org/10.1088/1742-6596/895/1/012077

Vygotsky, L. S., & Cole, M. (1978). *Mind in society: Development of higher psychological processes*. Harvard university press.

Wada, T., Otagaki, T., & Kojiri, T. (2019). Externalization support for hypotheses creation process of discovery learning in biology. *ICCE 2019 - 27th International Conference on Computers in Education, Proceedings*, *1*, 87 – 89. https://www.scopus.com/inward/record.uri?eid=2-s2.0-85077690666&partnerID=40&md5=e9cfe0085a266d8da715d0e0a3540eb7

Yanti, W. T., & Fauzan, A. (2021). Desain Pembelajaran Berbasis Mathematical Cognition Topik Mengenal Bilangan untuk Siswa Lamban Belajar di Sekolah Dasar [A Mathematical Cognition-Based Instructional Design on the Topic of Number Recognition for Struggling Students in Elementary School]. *Jurnal Basicedu*, *5*(6), 6367–6377. https://doi.org/10.31004/basicedu.v5i6.1728

Yerizon, Y., Putra, A. A., & Subhan, M. (2018). Student Responses Toward Student Worksheets Based on Discovery Learning for Students with Intrapersonal and Interpersonal Intelligence. *IOP Conference Series: Materials Science and Engineering*, *335*(1). https://doi.org/10.1088/1757-899X/335/1/012113