

Research Article

# Improving students' high-level mathematical thinking skills through generative learning models

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## ABSTRACT

The purpose of this study was to (1) analyze the achievement of high-level mathematical thinking skills of students who received learning with generative models and learning with conventional models, (2) analyze the increase in students' high-level mathematical thinking skills between those who receive generative learning models and conventional learning models, (3) See the effect of students' KAM (Initial Mathematical Ability) levels in the high, medium, and low categories on the high-level mathematical thinking abilities of students who receive generative learning models and conventional learning models, and (4) The magnitude of the interaction between the generative learning model and the KAM (Initial Mathematical Ability) level of students in the high, medium, and low categories on the improvement of high-level mathematical thinking skills of students who received generative learning models and conventional learning models. This research is experimental with a pretest-posttest control group design. Based on the results of this study, it can be seen that (1) there are differences in the attainment of high-level mathematical thinking skills between students who are taught by generative learning models and conventional learning models, (2) There is a significant difference in the improvement of students' high-level mathematical thinking skills between students who are taught with generative learning models and students who are taught with conventional learning models, (3) For the KAM level of students in the high, medium, and low categories, it does not significantly affect the improvement of high-level mathematical thinking abilities of students who obtain generative learning models and conventional learning models, and (4) There is no interaction between the KAM level (high, medium, or low) and the learning model towards increasing the high-level thinking skills of students who receive generative learning models and conventional learning models.

**Keywords:** Generative Learning Model; Higher-Level Mathematical; Thinking Ability; Teaching Mathematics

## 1. INTRODUCTION

Education, as one of the bases for developing science and technology, certainly plays an important role in people's lives. One of them is mathematics education, which is really needed, especially in the 21<sup>st</sup> century, which is full of competition. Teachers and lecturers need to pay attention to this when equipping students with useful knowledge and skills to answer future challenges. In connection with it, Soedjadi (1995) stated that mathematics as one of the basic sciences, both its applied aspect and its reasoning aspect, has a very important role in efforts to master science and technology. This means that to a certain extent, mathematics is controlled by all Indonesian citizens, both in its application and in its patterns of thinking. Furthermore, Soedjadi stated that school mathematics, which is part of the selected mathematics or basic interests in developing students' abilities and personalities as well as the development of science and technology, It is necessary to always be in line with the demands of students' interests in facing future life. This is in line with As'ari's opinion (Fadjar, 2007) that the characteristics of current mathematics learning are inline with As'ari's opinion (Fadjar, 2007) that the characteristics of current mathematics learning are more focused on procedural skills, one-way communication, monotonous classroom settings, low order thinking skills, depending on the textbook, routine questions and low-level questions are more dominant. Teachers rarely provide high-level thinking skills to students in mathematics learning, so when students are given non-routine questions and questions that require critical and creative solutions, they do not have difficulty solving them. Furthermore, Rofiah et al. (2013:18) stated that Higher thinking skills are the ability to connect, manipulate, and transform existing knowledge and experience to think critically and creatively in an effort to determine decisions and solve problems in new situations.

Based on the description above, it can be said that the ability to think at a higher level is One of the characteristics of mathematics learning required in the curriculum is that students are not only given low-level thinking skills. However, it is also hoped that teachers can provide high-level thinking skills to students in mathematics learning so that they get used to thinking outside the box and providing non-routine problems and open-ended questions.

In TIMMS 2001, it was found that Indonesian students' high-level mathematics abilities are still far behind those of ASEAN countries, such as Singapore, Malaysia, Vietnam. This is the impact of our learning at school, which still relies on textbooks, and teachers are not used to presenting material and giving practice only on questions with a single solution, routine questions, and rarely provide non-routine and open-ended questions and do not require students to think critically, creatively, and problem solving that requires connecting, manipulating, and transforming knowledge that students already have with their' new knowledge.

One learning model that is thought to be able to improve students' high-level mathematical thinking skills in mathematics learning is using a generative learning model. Generative learning is a constructivism-based learning model that places more emphasis on actively integrating new knowledge using knowledge that students already have. The generative learning model requires students to be active and free to construct their knowledge. Apart from that, students are also given the freedom to express ideas and reasons for the problems given so that they will better understand the knowledge they have formed themselves, and the learning process carried out will be more optimal. According to Osborne & Wittrock (1985), the application of generative learning models is a good way to find out students' thinking patterns and how they understand and solve problems well so that in later learning, the teacher can develop strategies for learning, for example, how to create an interesting, enjoyable learning atmosphere, and so on.

Based on the description above, it can be said that generative learning can provide challenges for students to solve mathematical problems and encourage them to be more creative, motivated to learn, confident, and self-sufficient. In the mathematics learning process, teachers are required to use non-routine and open-ended problems to solve problems in mathematics learning.

## 2. RESEARCH METHOD

This type of research is quasi-experimental with a pretest-posttest control group design. In this quasi-experimental research, the subjects are not randomly grouped, but the researcher accepts the subject's condition as is. (Ruseffendi, 2005: 52). In this research, two classes were used, namely the experimental class and the control class. The initial stage of this research is to determine the research sample. Then two classes were taken at random, namely one as the experimental class and one as the control class. This treatment was given to see its effect on the aspect being measured, namely students' high-level mathematical thinking abilities. The research design used in this research is as follows:



In this design, the grouping of research subjects is carried out randomly by class. The experimental group was given generative learning treatment (X), and the control group was given conventional learning. Then each research class was given a pretest and posttest (O). In this research, students' initial mathematics ability factors (high, medium, and low) were also involved. The population of this research is all 2018–2019 semester students. The selection of undergraduate mathematics education students as research subjects was based on considering the students' level of cognitive development at the formal operational stage, so it was deemed appropriate to use a generative learning model. Apart from that, first-semester students are still in the teenage stage, and at this time, students are in the process of finding their identity and building self-confidence. Meanwhile, the sample selected in this study were students selected from the KAM level (high, medium, and low) based on quiz test data for the 2018–2019 academic year. The distribution of research samples is presented in [Table 2](#).

**Table 1. Distribution of Research Samples**

School Level	Generative Learning Group	Conventional Learning Group	Amount
High	13	14	27
Medium	29	30	59
Low	9	4	13
Total	51	48	99

The variables in this research consist of three variables, namely: (1) Independent variables include learning; (2) dependent variable, including: students' high-level mathematical thinking abilities; and (3) control variables, including students' initial level of mathematics ability (high, medium, or low). The instrument used in this research is a test in the form of a description consisting of three questions. The test is given to measure students' high-level mathematical thinking abilities. The test was carried out twice, namely the pretest, which was carried out before the learning process, and the posttest, which was carried out after the learning process.

There are two types of data in this research, namely quantitative data and qualitative data. Quantitative data was obtained through the analysis of student answers on tests of students' high-level mathematical thinking abilities. then grouped based on the learning model used, namely generative learning and conventional learning, and the level of students' initial mathematical abilities (high, medium, or low). Qualitative data was obtained through observations of lecturer and student activities in implementing learning. This data was analyzed descriptively to support the completeness of quantitative data in answering research questions. The quantitative data processing is carried out through several stages, namely: First stage: carry out descriptive analysis of the data and calculate the pretest, posttest, gain, and normalized gain values. At this stage, it can be seen that there is a big achievement—a big increase in the high-level mathematical thinking abilities of students in classes that use generative learning and classes that use conventional learning. Following this the N-Gain formula used is:

$$\text{N-Gain} = \frac{\text{Posttest Score} - \text{pretest score}}{\text{Maximum Score} - \text{pretest score}}$$

**Table 2. N-Gain Value Criteria**

N-Gain Value	Criteria
$\text{N-Gain} \geq 0,70$	High
$0,30 \leq \text{N-Gain} < 0,70$	Medium
$\text{N-Gain} \leq 0,30$	Low

Source: Hake (1999)

The normalized gain score calculation was carried out because this research not only looked at student improvement but also looked at the quality of that improvement. In addition, the calculation of the normalized gain score is carried out with the aim of eliminating the student guess factor and the effect of the highest score so as to avoid biased conclusions. Hake (1999). Second stage: at this stage, statistical prerequisite tests are carried out, which are used as a basis for hypothesis testing, namely normality test and homogeneity test. Third stage: determine the achievement and improvement of students' high-level mathematical thinking abilities between the experimental class and the control class, determine whether or not there is an interaction between the independent variable and the control variable on the dependent variable in accordance with the hypothesis that has been put forward. Then, to test these differences, a test is used Mann Whitney, one-way ANOVA, two-way ANOVA, and continued with further different tests of pairs of data groups. (Post-Hoc) through General Linear Model and the entire statistical calculation uses the help of the program SPSS 22.0 for Windows.

Apart from carrying out quantitative analysis, researchers will also carry out qualitative analysis of the answers to each question, observation data, and student response data. This aims to further examine the students' high-level mathematical thinking abilities and to find out whether the implementation of learning is in accordance with the learning provisions set out in the two learning models.

### 3. RESULTS AND DISCUSSION

#### Results

In answering the problems raised and seeing the achievement of the objectives of this research, So data analysis is directed at comprehensively revealing students' achievement of high-level mathematical thinking skills after learning using generative models and conventional models. Apart from that, in this research, students' initial abilities were also identified based on their initial mathematics abilities (high, medium, and low).

**a. Description of Data on the Achievement of Students' High-Level Mathematical Thinking Abilities**

The test results show differences in the achievement of high-level mathematical thinking skills among students who receive generative learning models and conventional learning models, as shown in **Table 3**.

**Table 3. Mann-Whitney Test Results Post-Test Data for Mathematical Thinking Ability High Level by Learning Group**

Learning	High-Level Mathematical Thinking Ability			
	Comparison of Posttest Means	Z <sub>Count</sub>	Sig. (2-Parties)	Ho
Generative and conventional	83,24 > 76,94	- 3,150	0,002	Rejected

Based on **Table 3**, it can be seen that the average post-test score for high-level mathematical thinking abilities of students who received generative learning is higher than the average post-test score of students who received conventional learning. In **Table 3**, it can also be seen that the Z<sub>Count</sub> value is -3.150 and the Sig. (2-Parties) value is 0.002, which is less than the 0.05 significance level set. So, it can be concluded that there is a difference in students' achievement of high-level mathematical thinking skills between the group that received generative learning (experiment) and the group that received conventional learning (control).

**b. Description of Data on Increasing High-Level Mathematical Thinking Abilities**

The test results show differences in the increase in high-level mathematical thinking abilities of students who received generative learning and conventional learning, as shown in **Table 4**.

**Table 4. Mann-Whitney Test Results N-Gain Data Mathematical Thinking Ability High Level Based on Learning Group**

Learning	High-Level Mathematical Thinking Ability			
	Comparison of Posttest Means	Z <sub>Count</sub>	Sig. (2-Parties)	Ho
Generative and conventional	0,622 > 0,396	- 3,905	0,000	Rejected

Based on **Table 4**, it can be seen that the average N-Gain score for high-level mathematical thinking abilities of students who received generative learning is higher than the average N-Gain score of students who received conventional learning. In **Table 4**, it can also be seen that the Z<sub>Count</sub> value is -3.905 and the Sig. (2-Parties) value is 0.000, which is less than the 0.05 significance level set. So, it can be concluded that there is a significant difference in increasing students' high-level mathematical thinking abilities between the group that received generative learning (experiment) and the group that received conventional learning (control).

**c. The interaction between learning and initial mathematics abilities to improve students' higher-level mathematical thinking abilities**

High-level mathematical thinking ability data was obtained from a high-level mathematical thinking ability test on the topic Systems of Linear Equations in Two Variables. The results of testing the interaction between learning and initial mathematics abilities in increasing students' higher-order thinking abilities are presented in **Table 5**.

**Table 5. Two-Way ANOVA Test Results between Learning and Initial Mathematics Ability Students to Improve High Level Mathematical Thinking Abilities**

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Ho
Intercept	13,924	1	13,924	111,182	,000	
Learning	,757	1	,757	6,046	,016	Reject
Initial mathematics abilities	,651	2	,325	2,598	,080	Accept
Learning*Initial mathematics abilities	,005	2	,003	,021	,979	Accept
Error	11,647	93	,125			
Total	37,892	99				

Based on the calculation results in **Table 7**, it can be seen that the F value for students' initial mathematics abilities is 2.598 and the significance value is 0.080; this value is more than the 0.05 significance level set. This means that the hypothesis, which states that differences in initial levels of mathematical ability have no effect on increasing students' high-level mathematical thinking abilities, is accepted. Thus, it can be concluded that differences in initial levels of mathematical ability do not have a significant effect on increasing students' high-level mathematical thinking abilities.

In **Table 5**, it can also be seen that the F value for the learning group is 6.046 and the significance value is 0.016, which is less than the 0.05 significance level that has been set. So, it can be concluded that differences in the use of learning groups have a significant effect on increasing students' high-level mathematical thinking abilities. Meanwhile, the interaction between initial mathematics ability and learning has an F value of 0.021 and a significance value of 0.979, which is more than the 0.05 significance level set. Therefore, it can be concluded that the KAM level with generative learning models and conventional learning models together does not have a significant influence on increasing students' high-level mathematical thinking abilities.

## Discussions

Based on the results of research using a generative learning model on two-variable linear equation systems material using a generative learning model in the experimental class and a conventional learning model in the control class, it can be seen that:

### *a. Achievement of High-Level Mathematical Thinking Abilities*

To see the achievement of high-level mathematical thinking skills using the Mann-Whitney test It can be seen that the average achievement score for high-level mathematical thinking skills of students who receive the generative learning model is higher than the average achievement score of students who receive the conventional learning model. From the test results, it can also be seen that the significance value is less than the specified significance level. So, it can be concluded that there is a difference in the achievement of high-level mathematical thinking skills between students taught using generative learning models and conventional learning models. In line with the above, Suryadi (2012: 24) stated that high-level mathematical thinking abilities are essentially non-procedural thinking abilities, which include, among other things, the following: ability to search for and explore patterns to understand mathematical structures and underlying relationships; the ability to use available facts effectively and precisely to formulate and solve problems; the ability to create mathematical ideas meaningfully; the ability to think and reason flexibly through formulating conjectures, generalizations, and justifications; the ability to determine that a problem-solving result is logical. Furthermore, NCTM (2000:10) characterizes high-level thinking abilities as non-routine problem solving, namely problems involving an individual or group situation, in developing one or more solutions.

### *b. Increasing High-Level Mathematical Thinking Abilities*

To see the increase in students' high-level mathematical thinking abilities, the average N-Gain score is used. The average N-Gain score for students' high-level mathematical thinking skills taught using the generative learning model is higher than the average N-Gain score for students taught using the conventional learning model. From the test results, it can also be seen that the significance value is less than the specified significance level. So it can be concluded that there is a significant difference in increasing students' high-level mathematical thinking abilities between groups that use generative (experimental) learning models and group that used conventional learning models (control). From these results, it can be seen that in the teaching and learning process, lecturers must pay attention to matters related to learning, including: The learning model used, approach, strategy, or method includes the classroom atmosphere when learning takes place, because this can also influence students' way of thinking. In line with the Ritchhart et al. (Tamalene, 2010) stated in their research that A conducive classroom atmosphere can encourage students to think effectively and broaden their conceptions of thinking. This research also provides evidence that students' thinking concepts are easy to form and achieve the expected progress using concept maps.

### ***c. Interaction between Learning and Initial Mathematics Ability to Improve Students' Higher-Level Mathematical Thinking Ability***

The interaction between learning and students' initial mathematics abilities shows that the F value for initial mathematics abilities is 2.598. and the significance value is 0.080, which is more than the specified significance level of 0.05. This means that the hypothesis states that differences in initial levels of mathematical ability have no effect on increasing students' high-level mathematical thinking abilities So it can be concluded that differences in initial levels of mathematical ability do not have a significant effect on increasing students' high-level mathematical thinking abilities. Meanwhile, the F value for the interaction between initial mathematics ability and learning is 0.021, and the significance value is 0.979, which is more than the set significance level of 0.05. This shows that there is a significant interaction between the initial level of mathematics ability and learning in increasing students' high-level mathematical thinking abilities. So it can be concluded that the initial level of mathematical ability with generative learning models and conventional learning models together does not have a significant influence on increasing students' high-level mathematical thinking abilities. Meanwhile, the F value for the learning group is 6.046, and the significance value is 0.016, which is less than the set significance level of 0.05. This means that differences in the use of learning have no effect on increasing students' high-level mathematical thinking abilities. Based on the description above, it can be concluded that students who receive the generative learning model have a moderate initial level of mathematical ability. Meanwhile, if we look at the average N-Gain, the high-level mathematical thinking abilities of students who receive the generative learning model more than the average N-Gain in students' high-level mathematical thinking abilities who use conventional learning models.

### ***d. The interaction between learning and the initial level of mathematical ability (high, medium, and low) in increasing students' high-level mathematical thinking abilities***

For the interaction between the learning model and the initial level of mathematical ability (high, medium, or low), it appears that there is no interaction to increase students' high-level mathematical thinking abilities. This can be seen from the asymptote value (sig.) of 0.979. Thus, it can be said that students' initial mathematical abilities at a medium level tend to have a higher increase in their high-level mathematical thinking abilities, when compared with students' initial mathematics abilities at high and low levels. This indicates that students at a moderate initial level of mathematical ability have better increases in high-level mathematical thinking abilities, when compared with students with high and low levels of initial mathematics ability.

## **4. CONCLUSION**

Based on the results of the description and analysis of data in this study, then presented some conclusions as follows: 1) There are differences in the achievement of high-level mathematical thinking skills between students taught using generative learning models and conventional learning models. 2) There is a significant difference in the increase in students' high-level mathematical thinking abilities between students taught with generative learning models and conventional learning models. 3) For students' initial level of mathematical ability in the high, medium, and low categories, it does not have a significant effect on increasing the high-level mathematical thinking ability of students who receive generative learning models and conventional learning models. 4) There was no interaction between the initial level of mathematics ability (high, medium, or low) and the learning model in increasing the high-level thinking abilities of students who received the generative learning model and the conventional learning model.

## **CONFLICT OF INTEREST**

There are no conflicts of interest declared by the authors.

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