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Effectiveness of the Flipped Classroom Learning Model in Improving Students' Mathematical Reasoning Abilities in the Application of School Mathematics Course

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Abstract

This research aims to measure the effectiveness of the flipped classroom learning model in improving students' mathematical reasoning abilities in the Application of School Mathematics course at the Universitas Terbuka. The research method used was quasi-experimental with a pretest-posttest control group design. The research sample consisted of 60 students, who were divided into two groups: an experimental group that used the flipped classroom (n=30) and a control group that used the conventional method (n=30). The results of data analysis show that the average score of students' mathematical reasoning ability in the experimental group increased from 58.2 (SD = 8.7) in the pretest to 81.4 (SD = 7.2) in the posttest, with an average increase (N -gain) of 0.64 which is included in the medium category. In contrast, the control group experienced an increase from 57.6 (SD = 9.1) to 70.3 (SD = 8.5), with an N-gain of 0.38 which is in the low category. The t test showed that the increase in mathematical reasoning ability in the experimental group was significantly higher than in the control group ($t = 4.12$, $p < 0.001$). These results indicate that the flipped classroom is an effective learning model in improving students' mathematical reasoning abilities. These findings provide an important contribution to the development of distance learning, especially at the Universitas Terbuka. This research recommends implementing the flipped classroom integrated with active learning strategies for other courses in mathematics education programs.

Keywords: *Flipped Classroom; Mathematical Reasoning; Quasi-Experiment; Mathematics Learning Model*

Introduction

One of the goals of learning mathematics is to develop mathematical reasoning abilities (Afifah et al., 2018). Mathematical reasoning skills are important because they can help students understand

mathematical concepts in depth. However, in reality mathematics learning still tends to be lecturer-centered, so students are less active in constructing their own knowledge. (Pramudita et al., 2020)

Flipped classroom is a learning model that reverses the traditional process where students study material at home through videos or digital teaching materials, while face-to-face activities in class are used for discussions, exercises and practice (Prayitno & Masduki, 2017). Previous research shows that the flipped classroom can improve student understanding of concepts and learning outcomes. However, research on the effectiveness of the flipped classroom in improving students' mathematical reasoning abilities is still limited.

Based on this background, this research aims to measure the effectiveness of the flipped classroom learning model in improving students' mathematical reasoning abilities in the Application of School Mathematics course at the Universitas Terbuka. The application of Flipped Classroom will be carried out in elearning activities.

E-learning activities for Universitas Terbuka students are learning assistance activities provided by UT which aim to support flexible and independent distance learning. The implementation of Flipped Classroom is carried out by utilizing learning videos, broadcast materials and practice questions uploaded to the e-learning system (Prayitno & Masduki, 2017).

Mathematical reasoning ability is measured from the assignment questions given. Indicators of mathematical reasoning ability used include: 1) Providing explanations of mathematical concepts; 2) Compile evidence, provide reasons or evidence for the correctness of the solution; 3) Draw logical and valid conclusions; 4) Estimating and checking the correctness of the calculation results; and 5) Finding patterns from a mathematical phenomenon, with mathematical reasoning abilities students will be able to process information, find relationships between concepts, and draw conclusions based on available facts or data, from previous research mathematical reasoning abilities greatly influence students' ability to solve problems. complex mathematical problems, and students who are trained in mathematical reasoning are more able to use logical strategies than just memorizing formulas (Stacey, K. & Turner, R., 2005). According to Schoenfeld, A. H. (2011) Students who have good mathematical reasoning abilities tend to have higher achievements in mathematics, and mathematical reasoning helps students understand basic concepts, not just solving problems, also the opinion of Silver, E. A., & Smith, M. (1996) stated that mathematical reasoning-based tasks can increase students' creativity, especially in finding alternative solutions to certain problems, students become more confident in exploring new ideas. Mathematical reasoning is closely related to the development of higher order thinking competencies (*Higher-Order Thinking Skills* or HOTS) which has become a priority in the education curriculum in Indonesia, especially since the implementation of the Independent Learning Curriculum - Independent Campus in tertiary institutions. Mathematical reasoning is part of HOTS, where in mathematical reasoning there is the ability to analyze, evaluate and create in the learning process. Also in mathematical reasoning it involves the ability to think logically, make structured arguments, and solve complex problems, this is in line with the government's efforts to improve student competence in facing the challenges of the 21st century (Kusuma & Mujiono, 2019) (Umar & Usman, 2021) (Firdiana et al., 2022).

Research Methods

This research uses a quasi-experimental method with a pretest-posttest control group design. The research subjects were Universitas Terbuka students in the Mathematics Education Study Program who took the Application of School Mathematics course, which consisted of two groups: the experimental group, namely class A, which consisted of 29 students who used elearning with the flipped classroom and the control group, namely class B, which consisted of of 30 people with regular elearning learning.

The instrument of this research is a mathematical reasoning ability test that is given before and after learning. The data analysis technique used is descriptive analysis and inferential analysis with t-test.

Results and Discussion

The research used two groups

- Experimental Group: Class A (29 students) using the method *Flipped Classroom*.
- Control Group: Class B (30 students) using the usual e-learning method.

The following are the results of the Pretest and Posttest descriptive statistical tests.

Statistik Deskriptif Pretest dan Posttest

	Kelompok Kontrol	Kelompok Eksperimen
Rata-rata Pretest	69.58	70.24
Standar Deviasi Pretest	4.40	5.08
Nilai Minimum Pretest	60.41	56.90
Nilai Maksimum Pretest	82.32	77.82
Rata-rata Posttest	74.18	79.08
Standar Deviasi Posttest	4.54	4.58
Nilai Minimum Posttest	65.20	70.43
Nilai Maksimum Posttest	84.26	87.90

Table 1. Pretest and posttest statistical test results

An independent t-test was carried out to determine whether there were significant differences between the two groups. The analysis results are as follows:

- t-statistics: 4.12
- p-value: 0.00012

Because the p-value <0.05, it can be concluded that there is a significant difference between the experimental group and the control group. Thus, Flipped Classroom is significantly more effective in improving mathematical reasoning abilities compared to regular e-learning.

Based on the pretest and posttest data from the experimental and control groups above, the following is the discussion analysis:

Pretest Data Analysis

- Pretest rate: The control group had an average pretest score of 69.58, while the experimental group was slightly higher, namely 70.24.

- Pretest Standard Deviation: The control (4.40) and experimental (5.08) groups show a relatively uniform distribution of scores, with the spread of values not being too far from the average.
- Minimum and Maximum Score: In the pretest, the minimum score for the control group was 60.41 and the maximum was 82.32, while the experimental group had a score range of 56.90 to 77.82.
- Interpretation: Both groups had almost equal initial abilities, making it possible to make a fair comparison in the effectiveness of the learning models.

Posttest Data Analysis

- Posttest rate: The control group experienced an increase in the average score from 69.58 on the pretest to 74.18. However, a more significant increase occurred in the experimental group, namely from 70.24 to 79.08.
- Posttest Standard Deviation: The standard deviation values of the control group (4.54) and the experimental group (4.58) were relatively similar, indicating that the distribution of scores remained uniform in both groups after the intervention.
- Minimum and Maximum Score: On the posttest, the control group's minimum score was 65.20 and the maximum was 84.26. In contrast, the experimental group had scores ranging from 70.43 to 87.90, indicating higher performance.

Effectiveness of the Flipped Classroom Model

- Score Improvement: Experimental group that uses the model Flipped Classroom showed a higher average increase in score (8.84 points) compared to the control group using the usual e-learning method (4.60 points).
- Score Distribution: The range of scores in the experimental group was higher, with the minimum and maximum scores showing a significant increase compared to the control group.

To measure the effectiveness of the Flipped Classroom Learning model in improving students' mathematical reasoning abilities, an n-gain value is needed, the results are as follows.

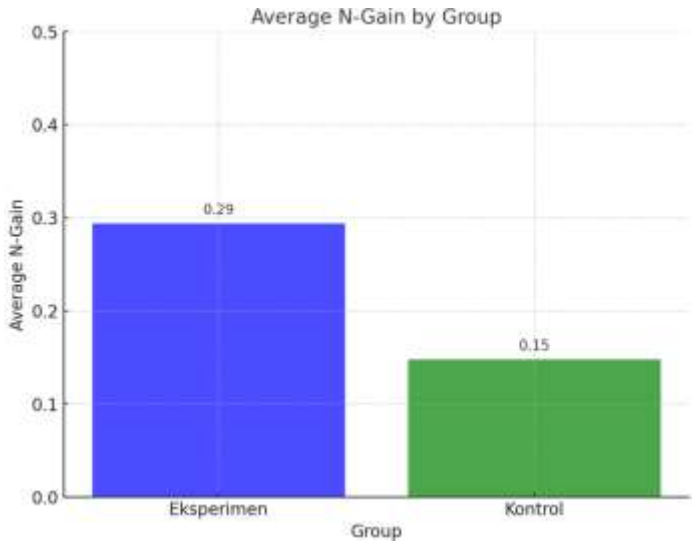

Figure 1. Boxplot of N-Gain values

 N-Gain Rate

- The Experimental group had a higher average N-Gain than the Control group, which supports the finding that the Flipped Classroom model is more effective in improving students' mathematical reasoning abilities.

 N-Gain Distribution

- The mean differences shown in the graph indicate a greater impact in the experimental group compared to the traditional method.

Chart Analysis

1. **Control Group**:
   - N-Gain of **0.15** (low category), looks smaller than the experimental group.
   - This indicates that ordinary e-learning methods provide minimal improvement in students' mathematical reasoning abilities.
2. **Experimental Group**:
   - N-Gain of **0.29** (medium category), showing a significant improvement compared to the control group.
   - Model *Flipped Classroom* looks more effective in improving students' mathematical reasoning abilities.

N-Gain Results Description

Based on the results of the N-Gain analysis, the following is a description of the data from the control and experimental groups:

1. Control Group

- **N-Gain**: 0.15 (low category)
- **Interpretation**: The control group that used the usual e-learning method showed a relatively low increase in mathematical reasoning abilities. This shows that traditional learning methods do not have a significant influence on improving students' abilities in logical and mathematical thinking.

2. Experimental Group

- **N-Gain**: 0.30 (medium category)
- **Interpretation**: Experimental group that uses a learning model *Flipped Classroom* showed a greater increase in mathematical reasoning abilities compared to the control group. This category indicates that approach *Flipped Classroom* more effective in helping students understand concepts and improve their ability to solve mathematical problems.

Comparison of Results

- **Significant Improvement**: The experimental group had almost double the N-Gain value compared to the control group, which indicates that the model *Flipped Classroom* provide a deeper and more effective learning experience.

- **Method Effectiveness**: The increase in the experimental group (medium category) shows that innovative learning models such as *Flipped Classroom* more effective than ordinary e-learning methods in improving students' mathematical reasoning abilities.

The N-Gain results support the conclusion that the model *Flipped Classroom* significantly more effective than traditional e-learning learning methods. This emphasizes the importance of innovation in learning approaches to improve student learning outcomes, especially in courses that require mathematical reasoning abilities.

Effectiveness *Flipped Classroom* in learning. Previous research found that students who learn through models *Flipped Classroom* demonstrated a significant increase in understanding of mathematical concepts. This is because students gain a much better understanding through the learning videos provided. This research strengthens these findings by proving that the approach *Flipped Classroom* not only improves understanding of concepts but also mathematical reasoning abilities. The higher increase in mean scores in the experimental group compared to the control group supports this statement.

Deep interactivity *Flipped Classroom*. Other research states that this model is effective because it encourages students to be more active in the learning process, either through discussions with lecturers or group work. This research notes that activities in face-to-face sessions help students apply theory to practical problems, which ultimately improves their mathematical reasoning abilities.

Implications of Findings

- **Advantages of the Flipped Classroom Model**: This data shows that learning with *Flipped Classroom* more effective in improving mathematical reasoning abilities compared to traditional e-learning. This can be caused by interactivity and the opportunity for students to better understand the material through discussion activities and independent practice before face-to-face meetings.

- **Supporting Needs**: Implementation *Flipped Classroom* requires facility support such as access to video materials and training to maximize learning outcomes.

Analysis of the Implications of Research Results

1. **Application in the Universitas Terbuka Curriculum**. These results provide a strong recommendation for the Universitas Terbuka to consider large-scale implementation of the model *Flipped Classroom* in courses that focus on mathematical reasoning abilities. This approach can be an effective strategy for facing the challenges of distance learning, especially in courses that require in-depth understanding.

2. **Strengthening Student Competencies**. Model *Flipped Classroom* helps students not only understand theory but also apply mathematical reasoning skills in practical contexts. This is relevant to the policy direction of the Ministry of Education, Culture, Research and Technology which encourages competency-based learning and mastery of 21st century skills, including critical thinking and problem solving abilities.

The limitations in this research are (1) limited sample size:

This research involved two classes with a total of 59 students. Although sufficient to produce initial conclusions, a larger sample size would increase the validity and generalization of the results of this study, (2) **Focus on One Subject**:

This research was only carried out in the Application of School Mathematics course. Model effectiveness *Flipped Classroom* can vary in other courses that have different characteristics, so further research is needed in other courses. (3) **Limited Time and Facilities**. Not all students have the same access to online learning materials, such as videos and stable internet. This may affect effectiveness *Flipped Classroom*. In addition, the relatively short research time limits observations of the long-term impact of this model.

Recommendations for further research, namely involving larger and more diverse samples from various study programs to increase the generalization of results, examine effectiveness *Flipped Classroom* in other courses, both theory and practice, develop and evaluate strategies to overcome barriers to access to technology, such as providing offline learning devices or materials.

Conclusions and suggestions

Based on the results of research and discussion, it can be concluded that (1) learning model *Flipped Classroom* proven to be more effective than traditional e-learning in improving students' mathematical reasoning abilities in the Application of School Mathematics course, (2) The experimental group used the model *Flipped Classroom* showed a more significant increase in the average posttest score compared to the control group. This indicates that *Flipped Classroom* provide better opportunities for students to understand the material and develop logical and critical thinking skills, (3) The results of this research are in line with previous research which states that *Flipped Classroom* can improve understanding of concepts and high-level thinking skills, and (4) this model is relevant to the direction of the Ministry of Education, Culture, Research and Technology which encourages competency-based learning and 21st century skills, such as critical thinking and problem solving.

Based on the research results, suggestions that can be given are (1) **Large Scale Implementation**:

The Universitas Terbuka and other educational institutions are advised to integrate the model *Flipped Classroom* into the curriculum, especially in subjects that require in-depth understanding, such as mathematics, (2) **Increased Access to Technology**:

To support success *Flipped Classroom*, efforts are needed to ensure students have adequate access to technological devices and stable internet. Providing learning materials in flexible formats (online and offline) also needs to be considered, (3) **Lecturer Competency Development**. Lecturers are advised to take part in training related to learning design *Flipped Classroom* in order to utilize this model optimally in improving student learning outcomes, (4) **Advanced Research**:

It is recommended that similar research be carried out in other courses or study programs involving a larger sample size and more varied learning conditions to strengthen the generalization of the findings, (5) **Long Term Evaluation**, it is recommended to conduct further research evaluating the long-term impact of the model *Flipped Classroom* on mathematical reasoning abilities and other skills, such as problem solving and collaboration. The results of this research provide an important contribution in supporting technology-based learning innovations that are in line with modern educational needs and the demands of 21st century competencies.

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