



Analysis of the Utilization of Digital Technology in the Flipped Learning Model to Improve Students' Conceptual Understanding

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ABSTRACT

This study aims to analyze the effectiveness of the utilization of digital technology in the flipped learning model on improving students' conceptual understanding. This study used a quasi-experimental design with a nonequivalent control group approach involving two classes of students: the experimental class (32 students) and the control class (33 students). The research instruments consisted of pretests and posttests and observation sheets, which were then analyzed using descriptive statistics, t-tests, and N-Gain. The results of the study showed a significant difference in the mean between the experimental and control groups, with $t = -9.206$ and Sig. (2-tailed) < 0.001 , indicating that the implementation of digital technology in flipped learning significantly influences students' conceptual understanding. The N-Gain value indicated that the improvement in the experimental class was in the moderate to high category, while the control class was predominantly in the low category. Thus, it can be concluded that the flipped learning model based on digital technology is more effective and positively affects students' conceptual understanding, particularly by increasing active engagement and independence in learning, compared to the traditional learning approach.

Keywords: innovative, digital, flipped learning, conceptual understanding

INTRODUCTION

The development of the digital era demands the integration of technology in education as an unavoidable necessity. Modern education still faces various problems, such as the low level of student engagement in the learning process, disparities in access to learning resources, and the dominance of traditional teaching methods that are less effective in improving students' conceptual understanding and learning motivation [1].

Many students still rely on lecturers' lectures without independently exploring the material; thus, the learning process becomes passive and less interactive [2]. On the other hand, the rapid development of technology has changed the way individuals acquire and manage information in everyday life [3]. However, the limited time in face-to-face sessions also often constrains students in exploring the material more deeply [4]. The limited time in face-to-face sessions also limits students' ability to explore the material more deeply. This condition indicates the need for innovation in learning models that can increase students' active participation as well as support the strengthening of human resource competencies (HR), in line with Asta Cita No. 4 and the goal of quality education in SDG No. 4 [5], [6].

The Flipped Learning model becomes one of the relevant approaches to address learning problems by reversing the traditional paradigm, namely assigning students to study the material before the class meeting through various digital resources, such as instructional videos, interactive modules, and online learning platforms [7]–[9]. Thus, the time in class can be focused on discussion, analysis, and the application of concepts. This approach increases student engagement as well as encourages them to think critically and actively in exploring the concepts learned [10].

The utilization of digital technology in the Flipped Learning model has great potential to improve students' conceptual understanding. With access to various digital learning resources, students can understand concepts more deeply before the class session begins [11], [12]. Although the Flipped Learning model and the utilization of digital technology have been proven effective for learning, most studies still focus on learning outcomes and student engagement in general. Studies that specifically emphasize improving students' conceptual understanding through the integration of digital technology in the Flipped Learning model remain limited. Therefore, the novelty of this study lies in analyzing the utilization of digital technology in implementing Flipped Learning, with a focus on

improving students' conceptual understanding as an indicator of learning success. Based on this description, the objective of this study is to analyze the utilization of digital technology in the Flipped Learning model to improve students' conceptual understanding. The results of this study are expected to serve as a foundation for optimizing the utilization of digital technology in learning in higher education.

Table 1. Research Design of the Nonequivalent Control Group Design

Pretest	Treatment	Posttest
O ¹	X	O ²
O ³		O ⁴

The sample in this study consisted of 65 Elementary School Teacher Education (PGSD) students from the 2022 cohort, divided into two classes, namely Class A with 33 students and Class B with 32 students. The sampling technique used was purposive sampling.

The instruments used were to collect data through observation sheets and conceptual understanding test items. The data analysis techniques

Table 2. Score Categories of Students' Ability

Score	Category
0 ≤ PK < 45	Very Low
45 ≤ PK < 65	Low
65 ≤ PK < 75	Moderate
75 ≤ PK < 90	Good
90 ≤ PK < 100	Very Good

Note: PK = Conceptual Understanding Score

Then, the N-Gain test was conducted to determine the improvement in students' conceptual understanding [15] using the following formula:

$$G = \frac{S_{pos} - S_{pre}}{S_{maks} - S_{pre}}$$

Description:

G = normalized gain

Table 3. Normalized Gain Values

Normalized Gain Value	Category
$g < 0.30$	Low
$0,30 \leq g \leq 0.70$	Moderate
$g > 0.70$	High

Meanwhile, the inferential statistical analysis in this study used the t-test (independent sample t-test) to determine the significant difference between the experimental class and the control class using SPSS version 27.

RESULT AND DISCUSSION

The results of observations conducted in the experimental class with 32 students showed a high level of active engagement in the learning process using the flipped learning model. This engagement was reflected in students' readiness to access the online materials, including instructional videos and reading materials, before the face-to-face sessions. The students also appeared to prepare notes, summarize the material, and identify parts that were not yet understood to discuss further in class. This condition indicates that the flipped learning model can encourage a change in students'

RESEARCH METHODS

This study was conducted at Universitas Muhammadiyah Sorong, Southwest Papua. This study used a quasi-experimental design with a non-equivalent control group design [13]. This design was used to assess the effectiveness of implementing digital technology in Flipped Learning on the conceptual understanding of Elementary School Teacher Education (PGSD) students. The following table presents the design for the non-equivalent control group.

included descriptive and inferential analyses. Descriptive analysis was used to describe students' conceptual understanding, while inferential analysis was conducted to assess significant differences between the experimental and control groups after the treatment. The scoring guidelines for students' conceptual understanding are presented in the following table [14].

S_{pos} = posttest score

S_{pre} = pretest score

S_{max} = maximum possible score

For the classification of normalized gain, refer to Table 3 [16].

learning behavior from passivity to greater activity and independence in managing the learning process.

The main activities observed in the learning process included group discussions, presentations, and question-and-answer sessions on concepts studied independently. The observations showed that students who previously tended to be passive became more willing to ask questions and express their opinions. The discussions became more interactive, with some students taking on roles as small facilitators within their groups. From a pedagogical perspective, this condition indicates that the flipped learning model not only increases student engagement but also develops academic communication skills and group collaboration, which are important components of 21st-century learning.

The results of the observations can be seen in Table 4, as follows;

Table 4. Observation Results

Analysis Aspect	Result
Number of Students	32 Students
Mean Score	35.22
Standard Deviation	2.76
Minimum Score	31
Maximum Score	41
Highest Score	41
Lowest Score	19

Based on Table 4, the analysis of the observation sheets for 32 students resulted in a mean score of 35.22 with a standard deviation of 2.76, indicating that variation among students is relatively small and the data tend to be homogeneous. In general, students showed a good level of engagement in aspects of accessing materials, making summaries, asking questions, participating in discussions, and thinking critically. The highest scores were achieved by students who actively sought additional resources and clearly presented the discussion's conclusions, whereas students with low scores tended to be passive in the discussion process and less likely to explore the material independently. This indicates that the level of student engagement is an important factor influencing the quality of conceptual understanding.

These findings are in line with the study conducted by Xiaoying, which states that the use of the flipped classroom in learning can improve learning motivation, classroom engagement, social interaction

skills, and independent learning ability through group activities [17]. Thus, students' active engagement in learning is not only an indicator of participation but also an important mechanism in developing deeper conceptual understanding.

Furthermore, the results of the homogeneity test showed that the significance values obtained, both based on the mean (0.165), median (0.169), median with adjusted df (0.170), and trimmed mean (0.165), were all above the significance level of 0.05. This condition indicates that the variance among groups is homogeneous, so the assumption of homogeneity is met and the analysis can continue using a parametric test. Methodologically, the fulfillment of the homogeneity assumption indicates that the differences in results obtained at the subsequent stage can be interpreted as the effect of the learning treatment provided, rather than as differences in initial characteristics among groups.

Furthermore, the results of the paired sample t-test statistics can be seen in Table 5 below:

Table 5. Independent Sample t-test Results

Statistik	Nilai
t	-9.206
Df	63
Sig. (2-tailed)	< 0.001
Mean Difference	-25.791
Std. Error Difference	2.802

Based on Table 5, the results of the independent samples t-test showed a significant difference in the means between the experimental and control groups, with a value of $t = -9.206$ and $\text{Sig. (2-tailed)} < 0.001$. Analytically, this result indicates that the implementation of digital technology in the flipped learning model significantly improves students' conceptual understanding. The mean difference of -25.791 indicates that students in the experimental group have a higher level of conceptual understanding than those in the control group using the traditional learning approach. These findings not only demonstrate the treatment's statistical success but also reflect the effectiveness of learning strategies that utilize digital technology to support students' independent learning processes. Digital technology enables students to access learning materials flexibly, repeatedly, and according to their individual learning pace. This process helps students build a deeper conceptual understanding by giving them the opportunity to study the material before face-to-face learning takes place. This is in line with previous studies stating that flipped learning interventions that utilize technology in learning can

increase student engagement and conceptual understanding [18].

In addition, the results of this study support previous findings that the flipped classroom learning approach significantly affects learners' affective and cognitive aspects, including learning engagement, motivation, self-efficacy, and thinking skills [12]. In addition, the results of this study support previous findings that the flipped classroom learning approach significantly affects learners' affective and cognitive aspects, including learning engagement, motivation, self-efficacy, and thinking skills.

Based on the categorization of N-Gain values, the experimental group showed a relatively good distribution of improvement in learning outcomes. Most students were in the moderate to high category, indicating that the implemented learning process produced gradual, sustained improvement in conceptual understanding. This improvement can be explained by the flipped learning model, which provides a more meaningful learning experience in which students not only receive information but also engage in analysis, discussion, and reflection on the concepts learned.

Table 6. N-Gain of the Experimental Class

Category	Category	Number of Students	Percentage (%)
Low	$g < 0.3$	28	84.8
Moderate	$0.3 \leq g < 0.7$	5	15.2
High	$g \geq 0.7$	0	0
Total		33	100

Conversely, Table 7 showed that in the control group, the majority of students (84.8%) remained in the low category, only 15.2% reached the moderate category, and no students reached the high category.

Table 7. N-Gain of the Control Class

Category	Category	Number of Students	Percentage (%)
Low	$g < 0.3$	4	12.5
Moderate	$0.3 \leq g < 0.7$	20	62.5
High	$g \geq 0.7$	8	25
Total		32	100

Overall, the comparison of N-Gain results between the experimental and control groups showed that the flipped learning model based on digital technology was more effective in improving students' conceptual understanding. This finding reinforced the theory that innovative, interactive, and student-centered learning approaches can produce better learning outcomes than conventional approaches.

Based on the results of the study, the treatment applied in the experimental class was proven to be more effective in improving students' conceptual understanding compared to the control class [7] [15]. Furthermore, the data showed a higher mean posttest score, a substantially greater N-Gain value, and t-test results indicating a significant difference.

The improvement in the experimental class can be explained by the applied intervention, which was able to provide a more meaningful learning experience, encourage students' active engagement, and improve conceptual understanding [11]. Conversely, in the control class that did not receive a similar treatment, the improvement in conceptual understanding was relatively small, although it was still statistically significantly increased.

Furthermore, the high correlation between the pretest and posttest indicated that students' initial ability was strongly related to the final learning outcomes. However, the learning treatment in the experimental group was proven to provide a significant additional contribution in improving students' conceptual understanding. This indicates that an appropriate learning intervention can strengthen students' initial abilities and accelerate the achievement of optimal learning outcomes.

Several other studies have shown that implementing digital technology in the flipped learning model can improve students' conceptual understanding, in line with recent findings. The results of a study conducted by Rahmatika showed that digital-based flipped learning had a significant impact on improving students' critical thinking skills through the strengthening of independent learning activities before

This finding further reinforced that learning using the traditional approach in the control class was less effective in improving students' conceptual understanding.

classroom learning [19]. This reinforces that the pre-class learning phase becomes a key element in developing deeper conceptual understanding.

In addition, Zhou emphasized that flipped learning had a positive impact not only on cognitive aspects, but also on affective aspects such as learning motivation and students' self-confidence [20]. This is consistent with the observation results of this study, which showed an increase in students' active engagement in discussions, presentations, and independent exploration of concepts.

Thus, the results of this study provide implications that integrating digital technology into the flipped learning model can serve as an effective pedagogical strategy to improve the quality of learning in higher education. This approach not only improves students' conceptual understanding but also promotes learning independence, active engagement, and critical thinking skills, which are highly needed to address the challenges of learning in the digital era [4]. Therefore, the implementation of the flipped learning model based on digital technology is worth recommending as an alternative innovative learning model to improve students' conceptual understanding in higher education contexts.

CONCLUSION

Based on the analysis of the discussion, the utilization of digital technology in the flipped learning model was effective as a learning strategy, improving students' conceptual understanding by strengthening active engagement, fostering learning independence, and using learning time more meaningfully for discussion and problem-solving. Thus, integrating digital technology into the flipped learning model can be recommended as an innovative learning approach that supports improving the quality of the learning process and developing students' conceptual understanding in higher education.

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