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Technology Integration in Learning Design to Improve PGMI Students' Mathematical Communication Skills on the Concept of Integers

Abstract

The development of technology encourages the world of education to be able to integrate it into learning design. By integrating technology into learning, students not only get more sophisticated tools to understand and manage mathematical concepts, but also strengthen their skills in communicating mathematical ideas clearly and effectively so that able to support the development of students' mathematical communication skills. Therefore, prospective elementary school teachers must prepare themselves to face the challenges of education in a better digital era. This study aims to analyze the effectiveness of technology integration such as YouTube, Kahoot, and PhET in learning design to improve mathematical communication skills of elementary school teacher education program (PGMI) students on the concept of integers. The type of research used is a quantitative approach with a quasi-experimental method with a posttest-only control design. The posttest-only control design was chosen for this study because the focus is on a direct comparison of the results between the experimental group and the control group after the treatment was given. The sample in this study involved 74 PGMI students who were divided into 38 students in the experimental group and 36 students in the control group. The experimental group received learning with technology integration, while the control group used conventional methods. Data were collected through a mathematical communication skills test. Data analysis used descriptive and inferential statistics, namely the independent sample t-test. The results showed that there were differences in the mathematical communication skills of the experimental group compared to the control group. The experimental group showed better abilities in terms of compiling mathematical arguments, using mathematical symbols and terms clearly, and effectiveness in explaining the concept of integers. Technology integration in learning has proven effective in improving students' mathematical communication skills on the topic of integers. These findings provide practical implications that the integration of technology in learning needs to be optimized to support mathematics learning in the digital era. Prospective teachers need to be prepared with the skills to use technology in learning design.

Keywords: Technology integration, Communication Skills, Learning Design

Abstrak

Perkembangan teknologi mendorong dunia pendidikan untuk dapat mengintegrasikannya dalam desain pembelajaran. Dengan mengintegrasikan teknologi ke dalam pembelajaran, mahasiswa tidak hanya mendapatkan alat yang lebih canggih untuk memahami dan mengelola konsep matematika, tetapi juga memperkuat keterampilan mereka dalam mengomunisasikan ide-ide matematika secara jelas dan efektif sehingga mampu mendukung pengembangan kemampuan komunikasi matematis mahasiswa. Untuk itu, calon guru sekolah dasar harus mempersiapkan diri dalam menghadapi tantangan pendidikan di era digital yang lebih baik. Penelitian ini bertujuan untuk menganalisis efektivitas integrasi teknologi such as YouTube, Kahoot, and PhET dalam desain pembelajaran untuk meningkatkan kemampuan komunikasi matematis mahasiswa Program Studi Pendidikan Guru Madrasah Ibtidaiyah (PGMI) pada konsep bilangan bulat. Adapun jenis penelitian yang digunakan ialah pendekatan kuantitaif dengan metode quasi eksperimen dengan desain kontrol posttest-only. Desain kontrol posttest-only dipilih untuk penelitian ini karena fokusnya adalah pada perbandingan langsung hasil akhir antara kelompok eksperimen dan kelompok kontrol setelah perlakuan diberikan. Adapun sampel dalam penelitian ini melibatkan 74 mahasiswa PGMI yang dibagi menjadi 38 mahasiswa kelompok eksperimen dan 36 mahasiswa kelompok kontrol. Kelompok eksperimen menerima pembelajaran dengan integrasi teknologi, sementara kelompok kontrol menggunakan metode konvensional. Data dikumpulkan melalui tes kemampuan komunikasi matematis. Analisis data menggunakan statistik deskriptif dan inferensial, yakni uji – t independent sampel t-test. Hasil penelitian menunjukkan terdapat perbedaan dalam kemampuan komunikasi matematis kelompok eksperimen dibandingkan kelompok kontrol. kelompok eksperimen menunjukkan kemampuan yang lebih baik dalam hal menyusun argumen matematis, penggunaan simbol dan istilah matematika secara jelas, serta keefektifan dalam menjelaskan konsep bilangan bulat. Integrasi teknologi dalam pembelajaran terbukti efektif dalam meningkatkan kemampuan komunikasi matematis mahasiswa pada topik bilangan bulat. Temuan ini memberikan implikasi praktis bahwa integrasi teknologi dalam pembelajaran perlu dioptimalkan untuk mendukung pembelajaran matematika di era digital. Selain itu, calon guru perlu dipersiapkan dengan keterampilan menggunakan teknologi dalam desain pembelajaran.

INTRODUCTION

The continuous advancement of the digital era has rendered the integration of technology in education indispensable, shifting it from a discretionary choice to an essential component of modern pedagogy (Srivastava & Srivastava, 2024). The incorporation of digital technology into the learning process brings about significant changes in educational methods. By utilizing digital technology, students can experience a more realistic learning experience (Haleem et al., 2022). Especially In the discipline of mathematics education, the use of technology can open up new opportunities to improve learning effectiveness.

Therefore, technology is crucial for teachers and prospective teachers, including PGMI students, to understand and master technology to utilize it effectively in the learning process (Fauzan et al., 2022); By achieving this mastery, they can maximize the potential of technology to enhance mathematics learning (Trisnawati et al., 2023).

Mathematics is an important subject and must be taught to all students, from elementary school to college level. The goal is to develop logical, analytical, structured, and critical thinking skills (Raxmonjonovich & O'sarovna, 2023). According to Fadilla et al., (2021), mathematics is a discipline with distinctive characteristics, consisting of logically structured concepts with relationships established through valid proofs. Currently, the use of technology in learning has become indispensable, as it can bring significant changes to teaching methods and help develop mathematical skills in a more effective and engaging way (Engelbrecht & Borba, 2024).

The correlation between concepts in mathematical material requires students to be able to explain both the relationships and differences among these concepts. This ability is part of communication skills. Mathematical communication skills are one of the main competencies that students must have, includes PGMI (Rahman et al., 2024). Mathematical communication skills are essential competencies that PGMI students must develop. These skills encompass the ability to express and interpret mathematical ideas both verbally and in writing, utilizing various forms such as tables, diagrams, pictures, formulas, or demonstrations (Anggriani & Septian, 2019; Soleh et al., 2020). Mathematical communication is elaborated in written and verbal that demonstrate clarity of ideas and concepts in mathematical content (Hodiyanto, 2017). Mathematical communication skills are abilities characterized by the ability to express mathematical ideas and concepts in a logical sequence (Morgan, 2020). The indicators used to assess students' mathematical communication skills are adopted from the mathematical communication standards proposed by NCTM in 2000 (NCTM, 2000) . The indicators of mathematical communication skills used in this study are: (1) Consolidating mathematical ideas or concepts in writing; (2) Interpreting mathematical ideas or concepts through graphs, images, or tables; and (3) Accurately expressing mathematical concepts.

Effective communication skills are essential not only for personal understanding among PGMI students but also for prepar-

ing them to become future educators capable of explaining mathematical concepts clearly and effectively to elementary school students (Uyen et al., 2021). However, the reality in the field shows that the mathematical communication skills of PGMI students, especially in written form, are still relatively low. The results of previous studies revealed that students often have difficulty in conveying mathematical ideas coherently and systematically (Nadlifah & Prabawanto, 2017; Maulyda et al., 2020; Turmuzi et al., 2021). This limitation poses a significant challenge in mathematics learning, necessitating innovative solutions to addres it.

One potential approach to overcoming this challenge is through the implementation of technology integration in learning design. The presence of technology-based media is expected to provide solutions to various challenges encountered in the field of education (Windasari et al., 2024). Technology-based media such as e-learning, educational applications, other digital platforms (such as YouTube, Kahoot, and PhET) have become essential tools in supporting the learning process in this digital era (Suharli et al., 2024). Several previous studies have shown the effectiveness of technology integration in learning. For example, Backfisch et al., 2021) highlighted that technologies play a critical role in integrating technology in a qualitatively high manner that largely depends on the particular context. In the context of mathematical communication skills, Ompusunggu & Sari (2019) and Sudihartinih et al., (2021) identified a significant increase in students who use technology to understand identified a significant improvement in students who used technology to understand and articulate mathematical ideas, particularly through digital-based educational applications.

However, studies that explore the influence of technology integration on mathematical communication skills, especially in PGMI students and in the topic of integers, are still limited. This study offers a new contribution by investigating in more depth how technology can be effectively integrated into mathematics learning design.

Based on this background, this study aims to explore how technology integration in learning design can improve mathematical communication skills of PGMI students, especially in understanding and explaining the concept of integers. This study will investigate various strategies and innovative approaches in integrating technology into the PGMI curriculum, as well as analyzing its impact on the development of students' mathematical communication skills. By understanding how technology can be effectively integrated to support the development of mathematical communication skills, it is expected to prepare prospective elementary school teachers to face the challenges of education in the digital era better. The findings of this research can serve as a foundation for developing more effective PGMI curriculum that equips future teachers to teach mathematics in the digital era, while also providing valuable insights for educators and policymakers to improve the quality of mathematics education at the higher education level.

METHODS

This study uses a quantitative research type with a quasi-experimental method. This design has a control group, but it cannot fully function to control external variables that affect the implementation of the experiment (Sugiyono, 2020) .

The sample in this study was 74 PGMI

students, involving two classes of PGMI students, each consisting of 36 control class students and 38 experimental class students who were selected purposively.

The design used was a posttest-only control design which is described in Table 1.

Table 1. Research design

Group	Treatment	Posttest
Experiment	X	T
Control		T

This posttest only control design research design emphasizes the comparison of treatments between the two groups: the control group and the experimental group, where the experimental group is the group given special treatment, in this study the use of integrated technology media while the control group did not receive special treatment, only using ordinary methods. Therefore, the conclusion regarding the effect of independent variables on the dependent variable is more accurate because both groups are equal (Lee, 2022).

The independent variable in this study is the integration of technology in learning design, with mathematical communication skills as the dependent variable, focusing on the concept of integers. The research instruments include mathematical communication skills tests, observation sheets, and student response questionnaires.

The concept presented in this lecture is the sub-topic of numbers. The pretest and posttest questions are the same. The integration of technology in learning design is in the form of digital media such as e-learning, You Tube, Kahoot, and Phet.

The procedure includes preparation of instruments, implementation of learning with different treatments in experimental and control groups, and data collection through pretest and posttest. Data analysis uses descriptive and inferential statistics, including prerequisite tests (normality and homogeneity) and hypothesis testing such as independent t-test or Mann-Whitney U test.

RESULTS AND DISCUSSION

Result

This study descriptively examines the mathematical communication skills of PGMI students regarding the concept of integers. It compares those who received technology-integrated learning with those who experienced conventional learning, followed by inferential statistical tests to validate the findings.

Description of PGMI Students' Mathematical Ability Results

Based on the research results, the posttest values obtained for the control group, which utilized conventional learning methods, and the experimental group, which employed technology-integrated learning for the concept of integers, are presented in Tables 2 and 3:

Table 2 Descriptive Statistics of Control Class Posttest

Statistics	Posttest
Lowest score	60.00
The highest score	91.00
Average	64.33
Standard Deviation	5.63

Tabel 3 Descriptive Statistics of Experiment Class Posttest

Statistics	Posttest
Lowest score	65,00
The highest score	100,00
Average	80,26
Standard Deviation	6,77

Based on tables 2 and 3 above, it shows that the mathematical communication skills of PGMI students in the control class are still relatively low with an average of 64.33 with a sample size of 36, the lowest value of 60 and the highest of 91 and a standard deviation of 5.63. While the mathematical communication skills of PGMI students in the experimental class are relatively high with an average of 80.26 with a sample size of 38, the lowest value of 65 and the highest of 100 and a standard deviation of 6.77. From the two posttest values, the average in the experimental class is higher with a difference of 15.93 compared to the control class, in addition the lowest value in the experimental class is higher with a difference of 5 points and a difference of 9 points for the highest value.

Students mathematical communication skills are grouped into very low, low, medium, high and very high categories. The frequencies and percentages obtained after the posttest are as follows:

Table 4 Result of Mathematical Communication Skills in Control Class

		Posttest	
Interval	Category	Frequency	Percentage (%)
0 – 54	Very low	0	0
55 – 64	Low	14	39
65 – 79	Medium	21	58.3
80 – 89	High	0	0
90 – 100	Very high	1	2.7
Amount		36	100

Table 5 Results of Mathematical Communication Ability in Experimental Class

		Posttest	
Interval	Category	Frequency	Percentage (%)
0 – 54	Very low	0	0
55 – 64	Low	0	0
65 – 79	Medium	14	37
80 – 89	High	19	50
90 – 100	Very high	5	13
Jumlah		38	100

Based on table 4 and 5 above, the posttest value of the mathematical communication ability of PGMI students in the control class is dominated by the medium category with a percentage of 58.3%, there are 14 students in the low category with a percentage of 39% and there is 1 person in the very high category with a percentage of 2.7%. While the posttest value *of* the mathematical communication ability of PGMI students in the experimental class is dominated by the high category with a percentage of 50%, there are 14 students in the medium category with a percentage of 37% and there are 5 students in the very high category with a percentage of 13% and none are in the very low or low category.

The posttest results of students between the control class and the experimental class can be seen in Figure 1.

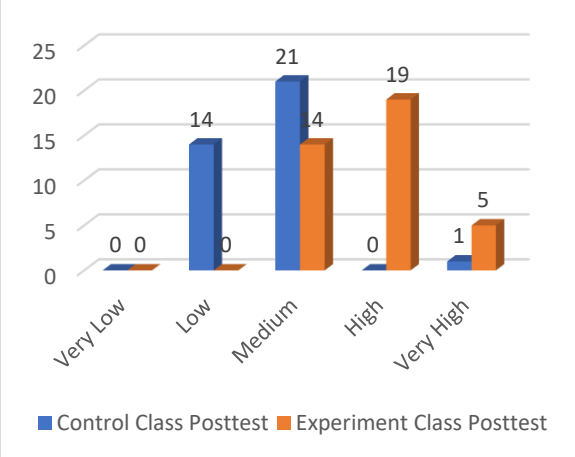

Figure 1. Results of the posttest of mathematical communication skills

Based on the results of the analysis, it can be concluded that there is a difference in the average mathematical communication skills of PGMI students between classes that use technology-integrated learning and classes that use conventional learning.

Tabel 6 Independent Samples Test

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means							
						Significance		Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
		F	Sig.	t	df	One-Sided p	Two-Sided p			Lower	Upper
Hasil Posttest	Equal variances assumed	1.930	.169	-10.969	72	<,001	<,001	-15.9298	1.4523	-18.8249	-13.0347
	Equal variances not assumed			-11.024	70.830	<,001	<,001	-15.9298	1.4451	-18.8113	-13.0483

The effectiveness of learning with technology integration in improving mathematical communication skills of PGMI students

This section evaluates the effectiveness of technology-integrated learning by analyzing whether there is a statistically significant difference in students' mathematical communication skills between the experimental and control groups. Inferential statistical methods are employed for data analysis. Specifically, the independent samples t-test is utilized to test the research hypotheses and assess preliminary assumptions.

Before the independent sample t-test, a prerequisite test was conducted, namely data normality test analysis and data homogeneity test analysis. With the help of IMB SPSS 29, the results indicated that the data were normally distributed, with a significance value (sig) greater than 0.05 (0.08 > 0.05), and that the variances were equal, as evidenced by a significance value (sig) greater than 0.05 (0.169 > 0.05).

After passing the normality and homogeneity tests, an inferential analysis was conducted using an independent samples t-test on the posttest results of both classes: the experimental class and the control class. The analysis yielded the following data:

Based on the results of the SPSS test above, because the significance value (sig) is less than alpha (α = 0.001< 0.05), it can conclude that there is a significant difference in the mathematical communication skills of PGMI students regarding the concept of integers between classes taught using technology-integrated learning and those taught using conventional methods.

After determining whether there is a difference between the experimental class and the control class, to find out whether the integration of technology in the learning design is effective or not, an independent sample effect size is used using IBM SPSS version 29.

Table 7 Independent sample effect size

Information	Cohen's d Estimate Value
Posttest Results	2,551

The result of the calculation of *the* effect size of technology integration in learning design to improve the mathematical communication skills of PGMI students obtained an effect size value of 2.551, meaning it is categorized as "very large". This shows that technology integration in learning design influences improving the mathe-

matical communication skills of PGMI students in integers.

Based on the results of the effectiveness test and effect size test, it shows that the integration of technology in the learning design that has been carried out is effective and has a very large influence in improving the mathematical communication skills of PGMI students in integers.

Discussion

The results of the analysis regarding the implementation of learning with technology integration showed that it was achieved both in terms of average and proportion. However, some students still faced challenges in solving integer problems, particularly when the questions were presented in narrative form and different from the examples provided, both in the experimental and control classes. One of the main obstacles in solving narrative problems is the difficulty of students in understanding the context of the problem presented through the story, identifying relationships between information, and linking the information to relevant mathematical concepts, while at the same time they were required to represent verbal information from the text into mathematical forms, such as diagrams, equations, or models, which are often a challenge in themselves. This also shows that students' mathematical communication skills in sub-integers have not yet developed well, when viewed within a period of one semester. In addition, seen from the learning factor, the improvement of the mathematical communication skills of PGMI students who apply learning with technology integration is still not optimal because in its implementation there are still several obstacles. For this reason, learning with technology integration needs to be developed more innovatively by considering the findings in this study.

Technology integration in mathematics learning is supported by the Cognitive Load Theory (Sweller, 1994) which states that the use of assistive devices such as technology can reduce cognitive load in processing complex information. Visualizations provided by applications or technological devices, such as interactive graphics or mathematical simulations, help students allocate more brain capacity to understand the core of the concept rather than processing separate elements. In the context of learning integers, technology can help PGMI students understand the relationship between positive and negative concepts through intuitive visual representations, thereby accelerating conceptual understanding. Pedagogically, the use of technology is in line with the theory of Constructivism (Piaget & Barbel, 2008; Vygotsky, 1978), which emphasizes the importance of active and contextual learning. Technology allows students to explore concepts independently through simulations and interactive exercises, so that they can build conceptual understanding based on direct experience. In this process, technology also acts as a "scaffolding" or learning support, providing additional guidance such as direct feedback that accelerates concept mastery.

The results of the study described above indicate that students who engage in technology-integrated learning demonstrate greater improvement in mathematical communication skills compared to those who receive conventional instruction. This suggests that technology integration positively impacts the enhancement of students' mathematical communication abilities. Supporting this finding, research conducted by Sukmawati & Purbaningrum

(2023) highlights the effectiveness of using Learning Management Systems (LMS) in blended learning environments to enhance students' mathematical communication skills. Similarly, Bahri (2020) and Nadlifah & Putri (2023) also found in his research that the use of e-learning in learning process can improve students mathematical communication skills. Therefore, technology-integrated learning is an effective approach for enhancing the mathematical communication skills of PGMI students, particularly in the context of integers

Implications of Research

Learning through effective technology integration can be applied to improve mathematical communication skills of PGMI students in integers. The implications of this study include the importance of emphasizing technology-integrated learning in teacher education curriculum design to improve basic mathematics skills, exploring innovative tools and methodologies to further develop mathematical communication skills and investigating the scalability of interventions in various educational contexts, and training educators in the effective use of technology in the classroom to maximize its impact on student learning outcomes.

Limitation

The limitations of this study include the concept raised only in the form of integers, the intervention was carried out in a limited time, so the long-term impact of technology cannot be measured, students who are not yet familiar with the Phet web menu, the use of media is limited to certain tools, without utilizing sophisticated technology such as AI or AR/VR, mathematical communication skills are only measured through written tests, without covering aspects of oral or collaborative communication.

CONCLUSION

Based on the results of the research and discussion in this study, the following conclusions were obtained: (1) the average mathematical communication ability of students using conventional learning was obtained for the posttest of 64.33 with a standard deviation of 5.63; (2) the average mathematical communication ability of students using learning with technology integration was obtained for the posttest of 80.22 with a standard deviation of 6.77; (3) inferential statistical analysis obtained a value of signifikansi is less than alpha (0.001 < 0.05), and it was concluded that there was a significant difference in students' mathematical communication skills using learning with technology integration. And the effect size results obtained were 2, 551 with a very large category. This means that learning with technology integration is effective in improving PGMI students' mathematical communication skills on the concept of integers.