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MATHEMATICAL ENGAGEMENT IN INTERACTIVE LEARNING: A CASE STUDY OF THE USE OF LUMIO IN UNDERSTANDING THE CONCEPT OF NORMAL DISTRIBUTION

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ABSTRACT

Understanding the concept of normal distribution in statistics is often challenging for students, as it requires a deep understanding of symmetry, probability distribution, and the use of normal distribution tables. These challenges are often caused by difficulties in connecting theoretical concepts with data visualization and in comprehending z-score transformations. This study aims to analyze students' mathematical engagement in understanding the concept of normal distribution using Lumio-based interactive media. The study employed a quantitative, quasi-experimental design, with a pre-test post-test control group design. The experimental group engaged in learning using Lumio-based interactive media, while the control group received traditional lecture-based teaching methods. The research instruments included a concept comprehension test, a mathematical engagement questionnaire, and an analysis of Lumio activity logs. The data were analyzed using paired sample t-tests and ANCOVA to evaluate the effectiveness of Lumio in improving students' mathematical engagement and conceptual understanding. The results showed a significant difference between pre-test and post-test scores in both the experimental and control groups. The experimental group, which used Lumio, showed a significantly higher improvement in both conceptual understanding and engagement compared to the control group. The findings suggest that using Lumio-based learning significantly enhanced students' engagement and understanding of normal distribution, compared to the conventional teaching methods.

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INTRODUCTION

Mathematical engagement is crucial in learning, as it reflects the depth of students' cognitive, emotional, and behavioral involvement in mathematical tasks (Lehtonen, 2022; Hartmann & Schukajlow, 2021). Ideally, students should not only understand abstract mathematical theories but also apply them to real-world problems. However, research indicates that many students experience low levels of engagement, particularly in subjects like statistics, which require understanding complex concepts such as normal distribution (Pashler & McDaniel, 2009; Ha et al., 2021). This lack of engagement can hinder their ability to fully grasp key statistical ideas, including the symmetry of the normal distribution, z-scores, and the relationship between probability and area under the curve (Ha et al., 2021; Fei et al., 2021).

The challenges of engaging students in learning the normal distribution are compounded by cognitive barriers such as difficulty in visualizing the concept and the transformation of z-scores (Janssen, 2021). According to studies by Rubin et al. (2022) and Mainali (2021), students often struggle to connect mathematical, graphical, and interpretive representations of this concept. Moreover, cognitive barriers such as difficulty in visualizing the normal distribution and understanding the transformation of z-scores contribute to these challenges (Janssen, 2021). These issues underscore the need for more engaging and interactive learning approaches that bridge the gap between theory and application, thereby improving students' understanding and interest in statistics (Mayer & Moreno, 2007).

Interactive media, such as Lumio, has shown promise in addressing these challenges. By providing dynamic visualizations, simulations, and opportunities for direct interaction with statistical data, Lumio offers students a more hands-on approach to learning complex concepts (Mayer & Moreno, 2007; Hartmann et al., 2021). Unlike traditional static teaching methods, interactive tools allow students to actively engage with the material, promoting deeper understanding and retention of concepts (Lehtonen, 2022; Hartmann & Schukajlow, 2021). Previous research has shown that interactive media can foster mathematical engagement and enhance students' understanding of complex subjects like statistics (Mayer & Moreno, 2007; Tversky & Morrison, 2002). However, empirical evidence specifically examining how Lumio can improve students' engagement and understanding of normal distribution is limited (Marupudi et al., 2024; Strunk et al., 2024). This study aims to fill this gap by investigating the impact of Lumio-based interactive learning on students' mathematical engagement with normal distribution concepts.

In addition to its dynamic capabilities, Lumio provides a unique platform for real-time feedback and personalized learning experiences. By enabling students to visualize abstract statistical concepts, interact with simulations, and receive immediate feedback, Lumio fosters a deeper understanding of statistical principles and encourages active learning. Previous studies have emphasized the importance of immediate feedback and personalized learning environments in promoting student engagement (Schunk, 2012; Hattie & Timperley, 2007). This approach not only

helps students comprehend abstract concepts but also motivates them to engage more actively in the learning process. Furthermore, Lumio's interactive nature ensures that students are not just passive recipients of information but are actively involved in applying the concepts they learn to real-world problems, which is essential for mastering complex subjects such as statistics.

METHOD

This study used a quantitative method with a quasi-experimental approach to measure the effectiveness of Lumio in increasing students' mathematical engagement in understanding the concept of normal distribution. The quasi-experimental design is widely used in educational research, particularly in settings where random sampling is not feasible (Dittrich, 2022; Scholtz, 2021). This approach allows researchers to study the effects of interventions in real-world classroom settings, where random assignment to groups is often not possible (Johnson & Christensen, 2020). By utilizing a pre-test post-test control group design, this study aims to assess how Lumio-based learning impacts both conceptual understanding and mathematical engagement compared to traditional teaching methods (Cohen, 1988; Schunk, 2012).

The population for this study consisted of students enrolled in statistics courses at the Mathematics Education Study Program at Serang Raya University during the academic year 2024. The total number of students in this population was 60, and from this group, a purposive sampling technique was employed to select participants. Purposive sampling was chosen because the researcher wanted to ensure that the selected students had prior exposure to basic statistical concepts and could participate actively in the learning activities involving Lumio. This technique allows for the selection of students who are best suited for the study's objectives, ensuring that the sample is relevant to the research questions (Patton, 2015).

From the total population, 28 students were selected: 15 students were assigned to the experimental group (using Lumio) and 13 students to the control group (using traditional methods). The reason for this unequal allocation is based on class sizes and scheduling constraints that limited the number of students who could be included in each group. The experimental and control groups were matched as closely as possible in terms of prior knowledge and academic performance to reduce potential biases in the study (Bryman, 2016).

The research instruments consisted of:

1. A normal distribution concept comprehension test (pre-test-post-test) to measure the increase in student comprehension.
2. A mathematical engagement questionnaire, which was developed based on indicators of cognitive, affective, and behavioral engagement in mathematics learning (Schunk, 2012).
3. Observation of learning activities to see student interactions in the learning process using Lumio.

Table 1. Normal Distribution Concept Understanding Test Instrument Grid

Purpose of the Question	Indicators of Conceptual Understanding	Question Item
Identifying the characteristics of normal distribution	Students are able to explain the nature of normal distribution.	1, 2
Using the normal distribution formula	Students can calculate probabilities using the normal distribution.	3, 4
Analyzing the relationship between normal distribution and real data	Students are able to interpret data in the context of normal distribution.	5, 6

To ensure the validity and reliability of the instruments, they were first tested for reliability and validity prior to the main study (Fink, 2013). The Lumio-based teaching materials were specifically developed for the experimental group to support interactive learning in understanding the concept of normal distribution.

Once the preparation stage was completed, the implementation stage began, where the experimental group engaged with Lumio for learning, while the control group used traditional methods. Pre-test and post-test measurements were used to assess the impact of Lumio on students' understanding of normal distribution.

The final stage involves the quantitative analysis of data collected from pre-tests and post-tests to measure students' mathematical engagement in understanding the concept of normal distribution. The focus of the analysis is on how mathematical engagement, as measured through both the comprehension test and the engagement questionnaire, changes as a result of the learning treatment. The data will be analyzed using paired sample t-tests to assess significant differences in students' engagement levels between the experimental and control groups. Furthermore, effect size calculations will be included to assess the magnitude of the impact of Lumio on students' mathematical engagement. To account for any potential pre-existing differences between the groups, ANCOVA will be used to control for baseline scores. The engagement questionnaire results will also be analyzed using descriptive statistics to identify patterns in cognitive, affective, and behavioral engagement throughout the learning process.

The proposed research flowchart can be seen in Figure 2.

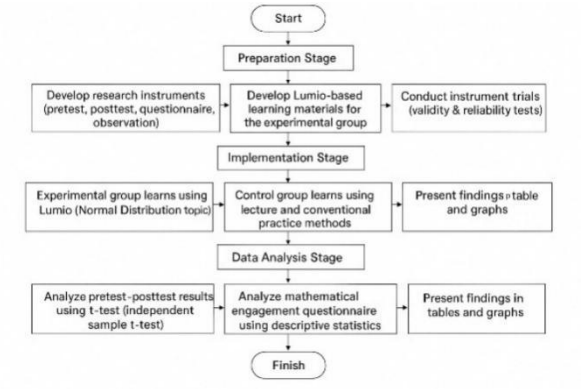

Figure 2. Research Flow Chart

The detailed stages of the research, along with the targets achieved and their indicators, are presented in Table 2 below.

Table 2. Research Stages, Targets, and Achievement Indicators

No.	Research Stages	Research Target	Indicators of Success
1	Preparation	Developing instruments and validation	Valid and ready-to-use instruments
2	Implementation	The use of Lumio in learning	Students actively use Lumio
3	Data Collection	Collecting pre-test-post-test results and questionnaires	Data collected as needed for analysis
4	Data Analysis	Testing the difference in learning outcomes between groups	Significant differences were found between the groups

RESULT AND DISCUSSION

This section presents the findings and discussions obtained through the stages of research that have been conducted. The data obtained is quantitative data, namely concept comprehension tests. Quantitative data processing was carried out using IBM SPSS Statistics 28.00 for Windows software.

Analysis of Mathematical Engagement in Understanding the Concept of Normal Distribution

The research aimed to measure mathematical engagement in understanding the concept of normal distribution, combining both conceptual understanding and engagement. This combined construct was evaluated through pre-test and post-test results as well as the mathematical engagement questionnaire.

The data showed significant improvements in both conceptual understanding and student engagement in the experimental group, which used Lumio, compared to the control group that followed traditional teaching methods. Table 3 presents the descriptive statistics for the pre-test and post-test scores on the concept comprehension ability for both groups.

Table 3. Descriptive statistics of concept comprehension ability

	Eksperiment class		Control Class	
Statistic	Pre-test	Post-test	Pre-test	Post-test
Number of sample	15	15	13	13
Average	61,87	82,27	60,69	72,08
Standar deviation	3,14	2,79	2,10	1,89
Minimum value	57	78	57	69
Maxsimum value	68	88	64	75

As seen in Table 3, both the experimental and control groups showed an improvement in their post-test scores. However, the experimental group, which engaged in Lumio-based interactive learning, demonstrated a significantly larger improvement compared to the control group, indicating a more substantial impact of Lumio-based learning on students' understanding of the normal distribution.

The experimental group's larger improvement suggests that Lumio played a key role in enhancing students' conceptual understanding of the material. Unlike traditional lecture-based methods, Lumio provided dynamic visualizations and real-time interaction, which allowed students to actively engage with the statistical concepts, making them more tangible and easier to grasp. In contrast, the control group, which used traditional methods, likely had fewer opportunities for interactive and visual learning experiences, which could explain the smaller improvement observed in that group.

These results highlight the effectiveness of interactive learning tools like Lumio in helping students overcome cognitive barriers when learning abstract concepts such as the normal distribution (Mayer & Moreno, 2007; Hartmann et al., 2021). The use of Lumio helped bridge the gap between theoretical understanding and practical application, ultimately leading to a deeper and more meaningful learning experience for the students in the experimental group.

To assess whether the differences in scores were statistically significant, the data were first tested for normality using the Shapiro-Wilk test. The results in Table 4 indicate that both the experimental and control groups had normal distributions, as all p-values are greater than 0.05.

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Table 4. Test of normality of the distribution of pretest data on conceptual understanding

		Test of Normality		
		Shapiro-Wilk		
	Class	Statistic	df	Sig.
Result	Pretest (Control)	.973	13	.924
	Postest (Control)	.955	13	.680
	Pretest (Experiment)	.976	15	.936
	Postest (Experiment)	.964	15	.768

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Based on the results of the Shapiro-Wilk test in Table 4, the p-values for both the experimental and control groups before the treatment (pre-test) are 0.936 and 0.924, respectively. Since these values are greater than 0.05, we accept the null hypothesis (H_0) that the data are normally distributed. Similarly, for the post-test data, the p-values for both groups are 0.768 and 0.680, indicating that the data are also normally distributed after treatment.

Since the data in both groups are normally distributed, the next step was to test the homogeneity of variances using Levene's Test, as shown in Table 5. The results of the homogeneity test show that the variances for both groups (experimental and control) are equal ($p = 0.231$), which supports the assumption of homogeneity of variance.

Table 5. Test of homogeneity of pretest and posttest data on concept comprehension ability

	Levene Statistic	df_1	df_2	*Sig.*
Pretest Postest	1.479	3	52	0.231

Based on the results of Levene's test in Table 5, the significance value is 0.231, which is greater than 0.05. This indicates that the variances for the pre-test and post-test data in both the experimental and control groups are homogeneous. Therefore, we proceeded with the paired sample t-test to compare the pre-test and post-test scores at a significance level of $\alpha = 0.05$.

The results of the paired sample t-test are presented in Table 6, which show whether there is a significant difference between the pre-test and post-test scores in both the experimental and control groups.

Table 6: Test of Equality of Pretest and Posttest Means

Group	t	df	Sig. (2-tailed)
Ekperimen	-18.072	14	0.000
Control	-32.556	12	0.000

The experimental group exhibited a significantly larger improvement in conceptual understanding compared to the control group, indicating that the Lumio-based treatment had a greater impact on improving students' understanding of the normal distribution.

ANCOVA: Adjusting for Pre-test Scores

An ANCOVA test was conducted to control for any initial differences in pre-test scores. The results in Table 7 indicate that even after adjusting for pre-test scores, the experimental group still showed a significantly higher post-test score ($F = 112.56$, $p = 0.000$). This suggests that the use of Lumio had a significant effect on

improving students' conceptual understanding of normal distribution, independent of their prior knowledge.

Table 7. Covariate Analysis Test

Source	Sum of Squares	df	F	P
Group	665.40642	1.0	112.56129	0.0
Pretest	4.06883	1.0	0.68829	0.4146
Residual	147.78758	25.0	nan	

Engagement Analysis:

The analysis of student engagement was conducted using the mathematical engagement questionnaire, which assessed students' cognitive, affective, and behavioral engagement. The results showed a significant increase in engagement in the experimental group ($F = 25.72$, $p = 0.00003$), suggesting that Lumio-based learning not only improved conceptual understanding but also significantly enhanced student engagement compared to traditional methods.

Table 8. Covariate Analysis Test for Engagement

Source	Sum of Squares	df	F	P
Group	0.66832	1.0	25.71959	3e-05
Pretest	0.00141	1.0	0.05433	0.81759
Residual	0.64962	25.0	Nan	

The data from the Lumio activity logs were analyzed to assess the level of interaction and engagement. We correlated the time spent on interactive exercises with improvements in pre-test and post-test scores. This allowed for a more detailed analysis of how the engagement metrics, as captured through Lumio's logs, influenced students' conceptual understanding and overall mathematical engagement. These findings are consistent with previous studies (e.g., Lehtonen, 2022; Hartmann et al., 2021) that emphasize the importance of interactive media in fostering mathematical engagement. Lumio's ability to provide dynamic visualizations and real-time interaction is in line with findings by Cohen (1988), who highlighted the significant impact of technology on students' engagement and understanding in complex subjects like statistics.

In addition, the data from the Lumio activity logs were analyzed to assess the level of interaction and engagement. We correlated the time spent on interactive exercises with improvements in pre-test and post-test scores. This allowed for a more detailed analysis of how the engagement metrics, as captured through Lumio's logs, influenced students' conceptual understanding and overall mathematical engagement.

CONCLUSION

Based on the results, both the experimental and control groups showed significant improvements in their post-test scores. However, the experimental group demonstrated a larger improvement in both conceptual understanding and engagement, underscoring the effectiveness of Lumio-based learning in enhancing mathematical engagement in understanding the concept of normal distribution.

This study highlights the potential of interactive media, such as Lumio, to improve both conceptual understanding and student engagement in complex subjects like statistics. The findings suggest that interactive media can provide an engaging learning experience that fosters deeper understanding of statistical concepts, especially for students who may struggle with abstract ideas such as the normal distribution.

Despite these promising results, the study is limited by the small sample size and the specific context of Serang Raya University. These limitations suggest the need for caution in generalizing the findings. Future research could expand the sample size to enhance the generalizability of the results and explore the long-term effects of interactive learning tools like Lumio in various educational settings. Further studies could also investigate the impact of Lumio on a broader range of statistical concepts and across different types of learners.

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AUTHOR CONTRIBUTIONS
Author One: Conceptualization, writing—original draft, editing, and visualization;
Author Two: Writing - review & editing, formal analysis, and methodology;
Author Three and Four: Validation and supervision.

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