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Enhancing mathematics learning in phase E: assessing Wordwall effectiveness

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ABSTRACT

The use of technology, classroom atmosphere, facilities, and learning resources can support quality learning outcomes in students. Wordwall, as a gamification tool, has been proven to be effective for elementary and junior high school students in mathematics. However, the effectiveness of Wordwall in enhancing senior high school students' cognitive abilities in mathematics learning has not been investigated. Previous studies have only shown its effectiveness in improving affective abilities. Therefore, this study endeavors to evaluate the effects of using Wordwall on the mathematics learning outcomes of senior high school students in phase E. Through quasi-experimental research with pre- and post-test group design, 38 experimental class students and 37 control class students were selected as samples in this study. The study found a statistically significant difference (sig. 0.000<0.05) in the mean learning outcomes of students who used Wordwall compared to those who did not. Descriptively, the experimental group displayed superior average mathematics learning outcomes compared to the control group, demonstrating a moderate level of effectiveness (ES=0.57). The strong effect of Wordwall can be realized if it is used not only as an exercise tool within the classroom but also as an instrument for knowledge transformation, incorporating consideration of students' learning styles.

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1. INTRODUCTION

Science and technology discipline is currently advancing rapidly, influencing various aspects of human life, including education. Since the 1970s, technology has transformed mathematics education and will undoubtedly play a major role in shaping the future of education compared to today. Educators realize the necessity to reconsider the entire education model and redesign it to be more student-centered [1]–[5].

Mathematics profoundly influences the attainment of the sustainable development goals (SDGs). Simultaneously, these goals facilitate the exploration of real-life situations within the realm of mathematics, fostering active learning for students [6], [7]. In this context, each learning objective in a mathematics lesson is linked to something meaningful for the students, incorporating aspects of their daily lives [8], [9]. Therefore, mathematics education can genuinely prepare human resources to compete in the global era. The obtained information reveals that the teaching and learning process lacks integration with technology. Consequently, students experience demotivation due to feelings of monotony and boredom associated with book-based learning and the limited communicative role of teachers. Low motivation leads to a decline in academic achievement [10]–[13]. To improve academic performance, students must consider psychological aspects such as learning preferences, self-efficacy, and goals for achievement [14], motivation [15], [16], interests [17], and the teaching and learning environment [18], [19].

Academic performance fundamentally encompasses skills related to knowledge, skills, attitudes, and values manifested in habits of thinking and behaving. Experiencing understanding “in action” involves integrating content knowledge and cognitive competencies with the demonstration of perspective, empathy, and self-awareness-qualities collectively termed as professional dispositions [20]. A potential remedy to enhance engagement and motivation in students involves the adoption of gamification. Gamification represents an approach that incorporates game components outside the typical gaming environment [21]–[25].

Utilizing virtual gamification platforms like Wordwall holds the potential to heighten students’ interest in their learning processes [26]–[28]. This approach is considered highly suitable for mathematics students, fostering engagement in various learning activities [29], [30]. Wordwall, functioning as an educational technology tool, is intentionally designed to facilitate interactive learning in diverse settings. It empowers both educators and learners to create personalized interactive materials, thereby enriching individual and collaborative learning experiences. These interactive resources are applicable in various pedagogical contexts, including formative assessment and gamified learning.

The Wordwall tool offers a wide array of templates, such as quizzes, matching exercises, word searches, and crossword puzzles, all of which can be customized to meet users’ specific needs. Noteworthy characteristics also encompass its accessibility, adaptability, and the potential for collaboration between student and teacher teams [31]. Wordwall is accessible via any web-enabled device, encompassing interactive whiteboards, tablets, desktop and portable computers, or smartphones. Its simplicity makes it user-friendly, facilitating easy operation for average users [32].

Several studies have developed instructional materials for mathematics using Wordwall, spanning from elementary to high school levels. While these materials have undergone valid and practical testing, not all products have been tested for effectiveness. Only a limited number of studies have investigated the effectiveness of using Wordwall in mathematics education, and these studies have been limited to elementary [33]–[35] and junior high school levels [30].

Regarding senior high school levels, the efficacy of Wordwall instructional materials tends to measure affective abilities, such as motivation and interest [36], as well as interactions among students [37]. No research has yet explored the effectiveness of Wordwall in enhancing mathematics learning outcomes at the senior high school or phase E level. Thus, this gap in the literature serves as the basis for conducting the present study. The current investigation addresses the following two research inquiries: i) is there an influence on the mathematics learning outcomes of phase E students after utilizing the Wordwall game for instruction?; and ii) what is the effectiveness of implementing the Wordwall game in improving the mathematics learning achievements among phase E students in mathematics instruction?

2. METHOD

Quantitative approaches with a quasi-experimental design, as delineated in Table 1, are utilized in the methodology of this study [38]. The research was conducted from September 29, 2023 to November 10, 2023, at senior high school in Riau Province, Indonesia, namely SMAN 4 Pekanbaru. All 11 classes of tenth-grade students at SMAN 4 Pekanbaru constituted the population for this study. The sample was randomly selected in groups to obtain two representative classes. This selection was facilitated using Wordwall to ensure the presence of the Wordwall usage atmosphere earlier.

The data collection instrument utilized in this research is specifically designed to evaluate the mathematics learning outcomes of students through the implementation of the Wordwall mathematical game. The Wordwall instructional tool used pertains to topics such as exponential functions and system of linear equations with two variables, which have been validated and proven practical [39]. The data collection instruments employed consist of pre- and post-test questions. The pre-test questions were administered to assess students’ mathematics learning outcomes before any treatment was applied to both classes, while the post-test questions were utilized to evaluate their outcomes after undergoing distinct treatments.

A testing technique was employed as the data collection method in this study. This technique was utilized to obtain data regarding the students' initial abilities before any treatment, which would be acquired through pre-test sheets conducted at the beginning of the session, and after the treatment, which would be obtained through post-test sheets conducted at the end of the session. The test results obtained were analyzed using both descriptive and inferential analyses. In the descriptive data analysis, the researcher examined the mean, standard deviation, as well as the minimum and maximum scores of students’ mathematics learning outcomes. In inferential data analysis, the researcher observed the differences in students’ learning outcomes using the assistance of SPSS v.25.

Table 1. Pre- and post-test design

Group	Initial assessment	Treatment	Final assessment
Select control group	Pre-test	No treatment	Post-test
Select experimental group	Pre-test	Wordwall treatment	Post-test

In addition to statistical tests, this study also employed a data analysis technique to find out the effectiveness of implementing the Wordwall game on students' mathematics learning outcomes when compared to conventional learning. This assessment will be measured using a metric known as effect size (ES). The formula and criteria for ES used are as in (1) [40].

$$ES = \frac{Mean\ of\ experimental\ group - mean\ of\ control\ group}{pooled\ standard\ deviation} \quad (1)$$

To calculate the pooled deviation, the formula should be as in (2).

$$SD_{pooled} = \sqrt{\frac{(N_E - 1){SD_E}^2 + (N_C - 1){SD_C}^2}{N_E + N_C - 2}} \quad (2)$$

Where, $N_E =$ number in the experimental group; $N_C =$ number in the control group; $SD_E =$ standard deviation of the experimental group; and $SD_C =$ standard deviation of the control group. The results of the ES calculation are interpreted as shown in Table 2.

Table 2. Criteria of ES

Criteria	Interpretation
$ES \leq 0.20$	Weak effect
$0.20 < ES \leq 0.50$	Modest effect
$0.50 < ES \leq 1.00$	Moderate effect
$ES > 1.00$	Strong effect

3. RESULTS AND DISCUSSION

3.1. Descriptive statistical analysis

The pre-test and post-test data collected are analyzed descriptively to calculate the average, standard deviation, lowest value, and highest value. These statistical measures provide a comprehensive understanding of the distribution and central tendencies within the dataset. A summary of the results of the descriptive analysis of pre-test and post-test data for phase E students is presented in Table 3.

According to the data presented in Table 3, it is evident descriptively that the mean mathematics learning achievements of students in both classes before the use of Wordwall in one class tend to be similar, with better data spread in the control class. The data in the experimental class (17.81) have a wider spread compared to the data in the control class (12.82). This difference arises because both classes have the same minimum value, but students who achieved the highest score were in the experimental class (63) with a significant difference of 22 points compared to the highest score in the control class.

After implementing Wordwall, there is a descriptive superiority in the mean mathematics learning achievement of students in the experimental class (98.37) compared to the control class, with an approximate 5-point difference in the average scores favoring the experimental group. The experimental class demonstrates a narrower data spread compared to the control class, as indicated by the smaller range observed in the experimental class (48) in contrast to the range observed in the control class (52). In essence, initially, both classes seemed to have the same quality. However, after the implementation of Wordwall in the experimental class, the learning outcome improved.

Table 3. Description of pre- and post-test data of students' mathematics learning outcomes

Descriptive statistics	Pre-test		Post-test	
	Experimental group	Control group	Experimental group	Control group
N	38	37	38	37
$\bar{X}$	27.01	28.13	98.37	93.43
SD	17.81	12.82	7.76	9.55
Min	0	0	52	48
Max	63	41	100	100

3.2. Inferential statistical analysis

Subsequently, to investigate the research inquiries, inferential statistical methods were applied to analyze the data. However, before conducting these statistical tests, assumption tests were performed, namely tests for normality and homogeneity of variance. The test of normality was conducted as a requirement for analysis of variance, while the variance homogeneity test was performed as a requirement for the t-test. If the data did not follow a normal distribution, a nonparametric test, specifically the Mann-Whitney test, would be employed without going through the homogeneity test series. The findings of the normality assessment for the pre-test data of students in both instructional cohorts are depicted in Table 4.

The criterion used for testing is that if the p-value (sig.) exceeds the predetermined significance level ($\propto$=0.05), then H_0 is accepted; otherwise, H_0 is rejected. The normality test employed is the Shapiro-Wilk test, as the data size exceeds 30. In the table, it is evident that the probability value (sig.) for one of the datasets is below 0.05. This implies that H_0 is rejected, leading to the conclusion that the data for both groups do not follow a normal distribution. Consequently, the equivalence test for pre-test data on student's mathematics learning achievements employs a non-parametric test, specifically the Mann-Whitney test, the outcomes of which are detailed in Table 5.

The testing criterion utilized is that if the p-value (sig.) exceeds the threshold of 0.05, then H_0 is accepted; otherwise, H_0 is rejected. In the table, it is noted that the probability value (sig.) exceeds 0.05, thus H_0 is accepted. Consequently, there exists no disparity between the pre-test data concerning mathematics learning achievements within the experimental class and the control class. After statistically confirming that both classes have the same average test scores, the next step is to analyze the post-test data to determine whether Wordwall has an effect on mathematics student learning outcomes. This analysis begins with a normality test, as depicted in Table 6.

Based on Table 6, it is evident that the probability value (sig.) for one of the datasets is below 0.05. Therefore, H_0 is rejected, indicating that the data for these two groups are not normally distributed. Consequently, the comparison of post-test data concerning students' mathematics learning achievements utilizes the Mann-Whitney test. The result is presented in Table 7.

Table 4. Normality test of pre-test data on students' mathematics learning outcomes

Shapiro-Wilk	Experimental class	Control class
Stat.	0.945	0.778
Df	38	37
Sig.	0.060	0.000

H_0: the sample is selected from a population exhibiting a normal distribution pattern.
H_1: the sample is selected from a population that is not exhibiting a normal distribution.

Table 5. Test of equality of pre-test data of student's mathematics learning outcome

Mann-Whitney	Z	Sig. (2-tailed)	H_0
612.000	-0.965	0.335	Accepted

$H_0: \mu_1 = \mu_2$; $H_1: \mu_1 \neq \mu_2$
Where, $\mu_1 =$ average pre-test data for mathematics learning achievement of students using Wordwall and $\mu_2 =$ average pre-test data for mathematics learning achievement of students not using Wordwall.

Table 6. Normality test of post-test data on students' mathematics learning outcomes

Shapiro-Wilk	Experiment	Control
Stat.	0.203	0.614
Df	38	37
Sig.	0.000	0.000

H_0: The sample is selected from a population exhibiting a normal distribution pattern.
H_1: The sample is selected from a population that is not exhibiting a normal distribution.

Table 7. Test of equality of post-test data of students' mathematics learning outcome

Mann-Whitney	Z	Sig. (2-tailed)	H_0
210.000	-5.480	0.000	Rejected

$H_0: \mu_1 = \mu_2$
$H_1: \mu_1 \neq \mu_2$
Where, $\mu_1 =$ average post-test data for mathematics learning achievement of students using Wordwall and $\mu_2 =$ average post-test data for mathematics learning achievement of students not using Wordwall.

According to the data, a probability value (sig.) being below 0.05 leads to rejecting the null hypothesis (H_0), suggesting a significant difference between the post-test data on mathematics learning outcomes in the experimental class and the control class. Moreover, based on descriptive data, the experimental class demonstrates superior mathematics learning outcomes compared to the control class. These findings suggest that the implemented Wordwall in the experimental class potentially contributes to enhanced mathematics learning outcomes when compared to traditional methods employed in the control class.

3.3. Effectiveness

In order to assess the efficacy of employing Wordwall on the mathematics learning outcomes of phase E students, the computation of the ES is conducted, as outlined in Table 8. This measurement enables a more profound comprehension of the magnitude and significance of Wordwall's impact on student learning outcomes, offering valuable insights for both educators and researchers. Through the quantification of the ES, researchers can ascertain the practical significance of utilizing Wordwall as an educational tool to enhance mathematics learning outcomes within phase E classrooms.

Based on the calculation results, the effectiveness of learning outcomes falls within the moderate criteria (0.57). The difference between this score and the strong category is quite significant. This is due to the minimal disparity between the average and data spread of the two classes. In the implementation of Wordwall usage in the classroom, grouping is carried out due to the prohibition of mobile phone use in Indonesian schools [41], [42]. Students are only permitted to use laptops, although not all students have access to these devices. Consequently, the formation of groups becomes an alternative to ensure that all students can use Wordwall collectively. Using their laptops, student groups access the provided Wordwall link to solve various types of questions, including short form, multiple choice, or matching.

However, challenges arise when there is uneven participation among students within the groups. Only a portion of students actively completes Wordwall tasks. Furthermore, some students who could easily solve exercises in the textbook face confusion when using Wordwall. Students are not yet familiar with the presentation style [43], [44]. This indicates that students within each group exhibit diverse characteristics [45] and learning styles [46]–[48], underscoring the importance of considering learning styles before the initiation of interventions. Moreover, it is advisable that Wordwall is designed not solely as an exercise tool but as a knowledge transformation instrument. The use of technology throughout the learning activities is believed to be more effective than its partial application. This strategy can enhance the effectiveness of Wordwall as an integral component of the educational process.

Table 8. Effect size of students' mathematics learning outcomes

Parameter	Value
N_E	38
N_C	37
SD_E	7.76
SD_C	9.55
SD_{pooled}	8.69
$\bar{x}_E$	98.37
$\bar{x}_C$	93.43
ES	0.57

4. CONCLUSION

In conclusion, this study demonstrated a statistically significant difference (sig. $0.000<0.05$) in the mean academic achievement of students who learned using Wordwall compared to those who did not. Descriptively, the experimental group exhibited higher average mathematics learning outcomes compared to the control group, with a moderate level of effectiveness (ES=0.57). The heightened effectiveness of Wordwall can be achieved by utilizing it not only as a classroom exercise tool but also as a medium for knowledge transformation, taking into account the diverse learning styles of students.

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