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THE EFFECTIVENESS OF WORDWALL-BASED STEM LEARNING ON UNDERSTANDING MATHEMATICS SUBJECT MATTER: OPERATIONS WITH WHOLE NUMBERS FOR ELEMENTARY SCHOOL STUDENTS

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Abstract. In today's educational landscape, many students struggle to develop a deep understanding of mathematical concepts, particularly in number operations, due to conventional and abstract teaching methods that lack real-world relevance. This study examines the effect of integrating STEM education (Science, Technology, Engineering, and Mathematics) with the Wordwall platform on enhancing elementary students' understanding of integer operations. Using a quantitative one-group pretest–posttest design, the research involved 46 fourth-grade students from SD Muhammadiyah Condongcatur. Students completed pre- and post-tests following the STEM–Wordwall learning intervention. The results revealed a statistically significant improvement in students' mathematical understanding, with a moderate effect size (Cohen's d=-0.540). The 95% confidence interval supported the effectiveness of the intervention. These findings align with previous studies emphasizing the positive influence of interactive digital tools on mathematical cognition and student engagement. Thus, integrating STEM principles with Wordwall effectively enhances learning outcomes and should be adopted to promote engaging mathematics instruction in primary education.

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INTRODUCTION

Learning is a process of interaction or communication between teachers, students, and various media sources used in both direct and indirect activities to enhance knowledge (Nurlatifah et al., 2022). Educators are responsible for creating engaging and innovative learning experiences that align with instructional objectives. Educators must select learning approaches that are suitable for the characteristics and needs of their students. The right approach aims to foster students' interest and motivation to learn. Learning approaches are usually defined as methods or strategies used to guide the achievement of learning objectives and facilitate educators in delivering material to their students (Djalal, 2017). The learning approach is another method used by teachers to help students understand lessons through various instructional techniques.

The best way to help students develop their skills, talents, and potential is by providing education (Amir, 2021). In the 21st century, which continues to experience technological advances, students, as the nation's future generation, need to have valuable skills and abilities to face various challenges of the times. According to Astuti et al. (2021), the rapid development of technology in various countries has permeated multiple fields, including economics, politics, socio-culture, and education. Educators face unique challenges in developing an educational system that produces graduates who are flexible, competitive, and possess a combination of knowledge and skills (Falentina et al., 2018). One method that can be used in education is STEM (Science, Technology, Engineering, and Mathematics) learning. This method aims not only to convey knowledge but also to enhance students' skills, enabling them to be applied in real-world situations in line with current times (Kelley & Knowles, 2016). STEM helps teachers prepare a generation that is reliable and skilled in the use of technology. STEM learning aims to shape a generation that has the opportunity to develop adaptive thinking skills, enabling students to face

challenges and changes, and compete at national and international levels. More specifically, STEM is an educational approach that combines four fields of science: mathematics, technology, engineering, and science (Amir, 2021). The main objective of STEM education is to improve students' critical thinking skills. With these skills, students can better understand the material they are learning and relate their knowledge to real-world phenomena (Wulandari et al., 2023).

In this regard, STEM learning helps develop knowledge and answer questions based on projects or investigations that have been carried out. STEM educators must have a strong understanding of the connections that can be made across domains by engaging with the community of practice. The information gained from the projects helps students acquire new knowledge (Amir, 2021). In STEM learning, project-based learning models differ from conventional project-based learning because they involve Wordwall technology. The goal of this approach is to increase student engagement through direct interaction with real objects, problem-solving, and the integration of technology into the STEM curriculum (Urbanová & Kotuľáková, 2019). Mathematics is a field of study related to calculation. Due to the interrelated nature of mathematical concepts, mathematics learning is categorized as contextual learning, which requires students to develop a deep understanding of the subject and critical thinking skills (Aulia & Kusmaharti, 2024). Several studies have shown that many students struggle to grasp mathematical concepts in depth (Made, 2018). This is due to a conventional, abstract learning approach that fails to relate mathematical concepts to real-life contexts (Nurjannah et al., 2019).

STEM learning is highly relevant to mathematics education because it connects numerical concepts with real-world problems and technological applications, thereby improving students' conceptual understanding (Agustina, 2024). STEM-based learning has been proven to improve students' problem-solving, critical thinking, and collaboration skills (Ferrara-Genao, 2015). Ling et al. (2019) emphasize that STEM integration can be achieved by arranging the sequence of disciplines within a subject or learning unit, thereby making STEM the primary focus of the educational process. This approach also encourages contextual, collaborative, and project-based problem solving. The STEM approach emphasizes four key elements: critical thinking, communication, creativity, and collaboration. This approach can help improve students' critical thinking skills, as demonstrated by their ability to solve problems, make informed decisions, and evaluate them effectively. This learning can significantly improve students' understanding of the material (Artobatama et al., 2020). To address these challenges, a STEM-based learning approach offers an alternative solution that can improve the quality of mathematics education. STEM emphasizes interdisciplinary integration and project-based learning, which can help students build conceptual understanding through direct experience (Bybee, 2013). Additionally, the integration of digital media, such as Wordwall, has been proven to increase student engagement and enhance the effectiveness of knowledge transfer in both online and offline learning environments (Widhiatama & Brameswari, 2024).

Several previous studies have explored the effectiveness of interactive media in mathematics learning; however, most remain limited to general applications without explicitly incorporating an integrative STEM-based approach (Maghfiroh et al., 2024). For instance, the study by Iswanto et al. (2024) demonstrated that the use of game-based interactive media can enhance elementary students' motivation to learn mathematics; however, it did not integrate elements of science, technology, engineering, and mathematics, as emphasized in the STEM approach. Meanwhile, Ningsih (2022) examined the use of Wordwall in teaching integer operations and found a significant improvement in students' learning outcomes; however, the study did not address the collaborative and contextual problem-solving aspects that are central to STEM learning.

Therefore, this research holds novelty by evaluating how the combination of the STEM approach and Wordwall media can influence students' understanding of whole number operations. Another study by Komarullah et al. (2020) also indicated that implementing interactive digital media can improve conceptual understanding in mathematics, though the applied approach remained conventional and lacked interdisciplinary integration. Conversely, the study by Hastina et al. (2025) demonstrated that STEM-based learning can enhance students'

critical thinking skills in geometry topics; however, it did not incorporate interactive digital media. Hence, this study is unique in its assessment of how the integration of the STEM approach and Wordwall media can impact students' comprehension of whole number operations. The integration of these two elements is expected not only to improve learning outcomes but also to foster students' critical thinking and contextual problem-solving skills.

Thus, this study offers novelty in evaluating the impact of combining the STEM approach with Wordwall media on students' understanding of integer operations. This study aims to analyze the effectiveness of the Wordwall-based STEM learning approach on the understanding of integer operations among fourth-grade elementary school students. The results of this study are expected to contribute to the development of contextual and enjoyable technology-based mathematics learning strategies. The use of technology as a medium of intervention in mathematics learning has an impact on student learning achievement, motivation levels, and attitudes toward the learning process (Higgins et al., 2019). Technology can make mathematics learning more interactive and engaging for students. Software, applications, and online platforms enable students to learn mathematics independently in a more enjoyable and accessible way.

Based on experience, many students believe that learning mathematics is challenging and not particularly enjoyable. Additionally, unengaging learning methods, where teachers provide lengthy explanations while students merely take notes, are a problem. Because this concept is often used in everyday life, arithmetic operations are among the fundamental concepts that students must master. Students who have a good understanding of these ideas can interact better and build a foundation for understanding more complex mathematical concepts (Karlimah et al., 2019). According to Wiryanto (2020), mathematics learning is not only an academic task but also serves as a tool and resource for improving students' skills. Mathematics has real benefits in everyday life, so teachers need to teach their students well from elementary school onwards. Teachers should use appropriate learning media to help students understand and apply concepts effectively. Effective mathematics learning not only helps students understand the subject matter but also encourages them to think logically, critically, and apply the ideas they have learned effectively (Sahoo et al., 2020).

Learning media plays a crucial role in the educational process, serving as a tool that helps students learn meaningfully in accordance with the stages of cognitive development, as outlined by Jean Piaget, specifically the formal operational stage. According to Widodo (2018), effective mathematics learning media are those that support students' understanding of abstract concepts in building mathematical understanding, combining visuals, interactivity, and contextualization. Therefore, teachers require effective educational media to help students focus more deeply and engage in the learning process. These media not only assist teachers in delivering lessons but also serve as tools to enhance students' interest and engagement in the subject matter. Additionally, the use of educational media can support students' learning processes and enhance their potential, particularly in mathematics, which demands a deep understanding of concepts. One medium considered quite adequate in learning is the Wordwall-based platform (Meysandi et al., 2024).

Wordwall is a web-based platform designed to create educational games in the form of fun interactive quizzes. Wordwall facilitates active engagement and collaboration among students through various activities such as matching pairs and class quizzes that can be done in groups (Patricio & Chicaiza, 2022). Using Wordwall not only sparks students' interest in learning but also enhances their intrinsic motivation, which ultimately contributes to improved understanding of the material and academic outcomes. This is evident from students' feedback, who report finding it easier to grasp the lessons and successfully passing exams after Wordwall was implemented in their learning (Len et al., 2021). Teachers and educators can create numerous games on this platform, enabling students to become more engaged in the learning process (Arni, 2023). Wordwall enables teachers to create a range of educational games with diverse themes, including quizzes, matching pairs, and finding similarities. This platform is ideal for learning because it can create a more interactive, dynamic, and enjoyable learning environment for students. According to Medina et al. (2024), their research found that Wordwall creates a fun, interactive, and engaging classroom atmosphere for students. Student activity and engagement

will also increase due to diverse learning activities that align with current times. Using Wordwall makes learning math more fun. It enhances student motivation and facilitates difficult visual-interactive learning (Hartono et al., 2024). Another study by Yanuarto & Setyaningsih (2024) demonstrates that Wordwall is an effective medium for mathematics learning; for example, a quasi-experimental study reported significant improvements in students' mathematics learning outcomes after using Wordwall.

Based on observations and interviews, the implementation of the STEM learning model at SD Muhammadiyah Condongcatur has not been optimal. The main obstacle faced is the lack of variety in effective learning methods and media. As a result, students' interest in learning has declined, which has impacted their learning outcomes, especially in mathematics. Additionally, limited resources are a factor that hinders the successful implementation of STEM learning at the school. This study focuses on three key indicators: students' understanding of whole-number operations, the application of the Wordwall-based STEM learning model, and the effectiveness of the learning process. To achieve optimal results, teachers must utilize learning models and media that can be tailored to meet students' individual needs. Additionally, teachers must have sufficient resources so that all students can fully participate in the learning process. Training and professional development for teachers are also necessary to ensure they have the skills and knowledge to implement STEM learning. Although technology and STEM methods can increase student engagement, this study will explore in more depth the effectiveness of the Wordwall-based STEM approach on mathematics understanding, particularly in whole number operations in 4th grade at Muhammadiyah Elementary School.

This study aims to answer two main questions: How effective is Wordwall in STEM learning, and how does using Wordwall affect students' understanding of whole-number operations? By answering these questions, this study aims to demonstrate the effectiveness of Wordwall in enhancing students' understanding of whole number operations. The results of this study are expected to enrich the scientific discourse on the effectiveness of interactive digital media in the context of STEM-based learning. This research presents a new perspective on how the integration of educational technology (Wordwall) and interdisciplinary approaches (STEM) can enhance students' conceptual understanding, particularly in whole-number operations, which form the foundation for higher-level mathematical mastery. Practically, this study provides implementable recommendations for teachers and elementary schools in designing more innovative, engaging, and student-centered learning experiences. The findings can serve as a reference for optimizing the use of Wordwall as part of an efficient interactive learning strategy that aligns with the characteristics of 21st-century learners.

RESEARCH METHODS

This study employs a quantitative approach, utilizing a one-group pretest-posttest experimental design. The purpose of this experiment is to determine the causal relationship between the variables studied. This method enables researchers to control classroom conditions, allowing them to assess changes before and after treatment (Akbar et al., 2023). The population in this study was all fourth-grade students at SD Muhammadiyah Condongcatur, Yogyakarta. The sampling technique used was purposive sampling, with a sample size of 46 students from one class who met the following criteria: (1) actively participated in mathematics learning, (2) had access to Wordwall, and (3) completed the pretest and posttest. The instrument used was a mathematics concept comprehension test in the form of multiple-choice questions with four answer options. Instrument validation was conducted through expert judgment, and reliability was assessed using Cronbach's Alpha in a limited trial, yielding a coefficient greater than 0.70, indicating high reliability (Arikunto, 2010). Data collection techniques were employed in two stages: a pretest to assess students' initial understanding prior to the treatment, and a posttest to measure the increase in understanding following the implementation of Wordwall-based STEM learning. The data were analyzed using a paired sample t-test to determine the significance of the difference between the pretest and posttest results. Next, to determine the magnitude of the effect, the effect size (Cohen's d) was calculated. The interpretation of the effect size refers to Cohen's

(1988) classification, namely small (d = 0.2), medium (d = 0.5), and large (d = 0.8).

RESULTS AND DISCUSSION

Based on data analysis, the mathematical understanding of fractions was tested using a Wordwall-based test instrument. The results showed that fourth-grade students at Muhammadiyah Condongcatur Elementary School demonstrated an understanding of addition operations with whole numbers. The following is a summary of the statistical description of the study's results.

Table 1. Descriptive Statistical Analysis

	N	Minimum	Maximum	Mean	Std. Deviation
Pretest	46	70.00	100.00	85.1739	7.50201
Posttest	46	72.00	100.00	87.2391	6.86759
Valid N (listwise)	46				

In Table 1, the data indicate that the maximum score on the pretest is 100, while the minimum score is 70. Meanwhile, on the posttest, the maximum score shows 100, and the minimum score shows 72. These values indicate an increase in scores from the pretest to the posttest. Next, to determine the data distribution, the data is tested for normality.

Table 2. Normality Test Results

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pretest	0.071	46	0.200*	0.978	46	0.544
Posttest	0.131	46	0.046	0.951	46	0.051

Based on Table 2, normality tests were conducted on the pretest and posttest data using two methods: the Kolmogorov-Smirnov and Shapiro-Wilk tests, as shown in Table 2. This test aims to determine whether the data is normally distributed, which is one of the important assumptions in parametric statistical analysis (Isnaini et al., 2025). For the pretest data, the normality test results indicate that the data are normally distributed, with significance values of 0.200 for the Kolmogorov-Smirnov and 0.544 for the Shapiro-Wilk. However, for posttest data, the normality test results show a difference between the two methods; the Kolmogorov-Smirnov test yielded a significance value of 0.046, below the 0.05 threshold, indicating that the data is not normally distributed. Conversely, the Shapiro-Wilk test yielded a significance value of 0.051, which is slightly above the 0.05 threshold, indicating that the data may still be considered normally distributed, although it is very close to the critical limit. In such conditions, the Shapiro-Wilk method is often more relied upon as it is more sensitive to small sample sizes (Winarti et al., 2024). Subsequently, hypothesis testing will be conducted to conclude the test results.

Table 3. Paired Sample Test Results

Pasangan	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval		t	df	Sig. (2-tailed)
				Lower	Upper			
Pair 1 Pretest - Posttest	-2.065	3.826	0.564	-3.201	-0.929	-3.661	45	< 0.001

After conducting a normality test, the study proceeded with a paired t-test to compare pretest and posttest scores. The results of the study, as shown in Table 3, indicate a significant difference between the two scores, with a p-value of 0.001 (< 0.05), which supports the rejection of H0. These findings suggest that implementing Wordwall has a substantial impact on improving students' understanding of mathematics. To assess the magnitude of this effect, the researchers used Cohen's d, calculated by dividing the mean difference by the standard deviation of the difference (Ediwarman & Pahamzah, 2023). For illustration, in a similar study, Sadeghi et al. (2022) reported a Cohen's d value of 2.197 in the Wordwall experiment group, indicating a very large effect (d > 2.0).

Table 4 shows the effect size of the difference between pretest and posttest scores using two methods: Cohen's d correction and Hedges' correction. Cohen's d value of -0.540 and Hedges' correction of -0.535 indicate that the change between pretest and posttest falls into the medium

effect category, according to Cohen's guidelines, which consider effect size values between 0.50 and 0.79 as medium effects (Siagian et al., 2023). The negative sign on the effect size value indicates a decrease in average scores, meaning the posttest score is lower than the pretest, or vice versa, depending on the measurement context.

Table 4. Paired Sample Test Results

Pair	Comparison	Standardizer	Point Estimate	95% Confidence Interval
Pair 1	Pretest - Posttest			
	Cohen's *d*	3.826	-0.540	[-0.847, -0.227]
	Hedges' correction	3.858	-0.535	[-0.840, -0.226]

This is in line with the explanation of Turmuzi & Lu'luilmaknun (2023), which states that a negative sign on the effect size describes the opposite direction of change in the mean between groups or measurement times. Additionally, the 95% confidence intervals for both effect sizes do not include zero (Cohen's d: -0.847 to -0.227; Hedges': -0.840 to -0.226), indicating that the differences are statistically significant (Azkia et al., 2023). According to Azkia et al. (2023), a confidence interval that does not pass through zero indicates that the differences between groups are not due to chance but instead have a real, practical effect. Overall, the results of this study indicate that the treatment given between the pretest and posttest had a significant impact. The level of effect obtained demonstrates an evident influence, indicating that the changes observed are not merely coincidental but rather the result of the intervention or the variable being studied.

After undergoing implementation testing with students, Wordwall-based learning media proved to improve the learning outcomes of fourth-grade students at Muhammadiyah Condongcatur Elementary School. Wordwall itself is a collection of vocabulary games that are systematically arranged and presented in large letters, which can be displayed on walls or through projectors to support interactive learning processes (El Khoury, 2011). Based on this explanation, Wordwall is a web-based application that offers a variety of educational games to help students learn words and sentences, serving as an interactive learning medium. It has an attractive appearance and a variety of enjoyable games. Students can increase their enthusiasm for learning by answering questions available through this platform. Wordwall can not only be used as a means of learning and playing in the classroom, but also allows students to participate and improve their understanding actively. This makes the material more engaging and easier to understand. Wordwall can also be used as a tool for creating and reviewing learning assessments. Therefore, teachers should frequently utilize such interactive learning tools to elevate educational standards and boost student motivation. Wordwall can be a practical choice, particularly for mathematics education, as it has been proven to enhance students' abilities. Based on the study's findings, "The Effectiveness of Wordwall-Based STEM Learning on Understanding Mathematics Subjects in Grade 4 Elementary School," several important discoveries were made that have a significant impact, both in the field of education and in the development of learning methods regarding the influence of STEM implementation on learning.

1. Increased Student Engagement

Wordwall-based learning, which combines STEM approaches, can enhance student engagement in mathematics, particularly in whole-number operations. Students who previously showed less interest in mathematics demonstrated increased interest after participating in game-based learning and interactive activities. Implications, increasing student engagement in learning plays an important role in increasing their motivation, which ultimately has a positive impact on conceptual understanding. Therefore, interactive platforms like Wordwall can be an effective solution to overcome challenges in elementary school mathematics learning, especially with materials that are often considered difficult, such as whole-number operations. With this approach, students can learn more actively and engagingly, thereby increasing their understanding of mathematical concepts. Bray & Tangney (2017) review of technology trends in mathematics education research shows that mobile applications and game-based learning approaches significantly increase student engagement in learning. This method emphasizes the importance of utilizing technology to make education more engaging, interactive, and relevant to students' needs

in today's digital era, and the expansion of knowledge about mathematical concepts.

The use of STEM-based learning, supported by Wordwall, has been proven to facilitate students' understanding of whole-number operations, including addition, subtraction, multiplication, and division. After practicing with this platform, students' ability to solve math problems involving whole-number operations has improved. Technology-based learning, which is interactive and contextual, as offered by Wordwall, enables students to receive immediate feedback and practice repeatedly. This method not only enhances their understanding of basic mathematical concepts but also helps them apply these ideas in everyday life. Therefore, the integration of STEM-based learning models with educational technology platforms, such as Wordwall, has excellent potential for facilitating a deeper understanding of mathematics at the elementary level (Darma et al., 2022).

2. Technological infrastructure challenges in some schools

Findings in several areas, especially in rural areas, reveal limitations in access to adequate technology infrastructure for the optimal implementation of Wordwall-based learning. This affects students' ability to utilize the potential of the digital platform fully. The limitations of technology infrastructure pose a significant challenge to implementing technology-based learning in many elementary schools. According to the digital divide theory by Warschauer (2003), this gap will directly impact the inequality of education quality. This includes the implementation of digital learning such as Wordwall, Google Classroom, and others. Therefore, the government and relevant parties must strive to make technology more accessible and available in schools, especially in remote or underdeveloped areas. Additionally, developing more accessible applications (e.g., with offline options) or training teachers to utilize technology effectively can be helpful solutions to address these challenges.

3. The gap in students' abilities in using technology

Findings indicate that not all students have the same level of technological skills, resulting in varied use of the Wordwall platform. Some students encountered difficulties when first using the application, but with sufficient practice and guidance, they eventually became proficient in it. The implications of differences in technological skills among students demand a more flexible approach to teaching technology in elementary schools. Teachers need to provide sufficient guidance so that all students can effectively utilize technology, including learning platforms like Wordwall. According to the Digital Literacy theory by Gilster & Glister (1997), it is stated that skills in using technology are not solely determined by the availability of devices but also by an individual's ability to understand, evaluate, and critically and effectively apply digital information. Thus, technology education in elementary schools must be an integral part of the curriculum to ensure all students have basic skills in using technology, which will be highly beneficial for future learning.

CONCLUSIONS AND SUGGESTIONS

Based on the research results, the use of Wordwall media in learning has been proven effective in improving student learning outcomes at SD Muhammadiyah Condongcatur. Throughout the study, a positive change was observed in students. Analysis showed a significant improvement in students' understanding of mathematics, with the rejection of H_0 as evidence of the intervention's success. A Cohen's d value of -0.540 was obtained from the effect size test, indicating that the change between the pretest and posttest falls into the medium effect category. With a 95% confidence level, the observed difference can be considered statistically significant, thus concluding that learning mathematics with Wordwall is an effective strategy for enhancing students' understanding. The application of Wordwall in the Mathematics subject of fraction material in Grade IV at SD Muhammadiyah Condongcatur has a significant impact on the understanding of Whole Numbers material. The average pretest and posttest scores increased from 85.173 to 87.239 after using interactive media, indicating that this method helps students better understand the ideas. STEM-based learning enables students to grasp concepts through hands-on exploratory activities and real-world scenarios. Nevertheless, the use of Wordwall is crucial in increasing students' willingness to learn and their engagement in lessons. With the combination

of both, learning becomes more interactive and enjoyable. It encourages all students, including beginners, to actively participate. This study demonstrates significant potential to enhance the quality of mathematics learning in elementary schools through innovative learning approaches that incorporate technology and interdisciplinary methods. Consequently, the use of this model can be suggested as an alternative teaching strategy that is useful and relevant to the educational challenges of the 21st century.

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