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Effect of Zencore-Based Adaptive Learning on Numeracy Literacy in Mixed Arithmetic Operations among Fourth-Grade Students

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Abstract. This study aims to analyze the effectiveness of the Zencore feature in the Zenius application as a form of adaptive learning to improve mathematics learning outcomes on the topic of mixed integer operations. A quasi-experimental design was employed, involving an experimental class that used Zencore and a control class that received conventional instruction. The research instruments included a pretest, posttest, and an observation sheet. The results showed a difference in the improvement of learning outcomes between the two classes. The experimental class demonstrated improvement in the medium category, while the control class showed improvement in the low category. These findings suggest that the Zencore feature supports students in understanding mixed integer operations at their individual learning pace.

Keywords: Numeracy Literacy, Mixed Arithmetic Operations, Adaptive Learning, Zencore, Elementary Mathematics, Learning Outcomes.

INTRODUCTION

Eucation plays an essential role in shaping the quality of human resources. However, the success of education is not only determined by access to schooling, but more importantly by the quality of learning processes that take place in the classroom. In recent years, ensuring effective learning has become increasingly challenging, especially since the COVID-19 pandemic. Prolonged school closures have resulted in significant learning loss across various educational levels worldwide (Sánchez et al., 2023). The World Bank (2022) also reported that the rate of learning poverty—defined as the percentage of children aged 10 who are unable to understand a simple text—reached 70% in low- and middle-income countries in 2022.

This condition is also evident in Indonesia. Beatty et al. (2021) revealed that the decline in students' mastery of basic mathematics competencies had occurred long before the pandemic, indicating the presence of structural challenges in classroom practice. Pascoe et al. (2022) emphasized that classroom instruction has often failed to account for differences in students' ability levels, causing students with weaker initial knowledge to fall further behind. This is in line with Akmal and Pritchett (2021), who explained that equal instructional time does not equate to equal learning outcomes. Uniform instruction tends to benefit higher-achieving students while widening learning gaps for those who are less prepared.

These findings are supported by field-based evidence. A survey of 34 sixth-grade teachers in Padang showed that 73.5% identified weak mastery of basic arithmetic operations as the main challenge in teaching mathematics, while 70.6% reported difficulties in providing individualized support due to heterogeneous ability levels within the same class. This indicates that mastery of fundamental arithmetic (Kabataku), which includes addition, subtraction, multiplication, and division, is a critical prerequisite for continued progress in mathematics learning.

Further research reinforces the importance of these foundational skills. Anisa and Kartini (2023) found that students' mathematical errors mostly occurred in procedural steps, suggesting that students struggle to execute solution processes even when they understand the concepts. Deringöl (2019) reported misconceptions in fraction learning, indicating that students' understanding of numerical meaning is not yet well established. Developmental research confirms this as well: Guerrero and Park (2022) argued that numerical concepts develop through arithmetic activity rather than memorizing number sequences. Long et al. (2016) and Ye et al. (2016) showed that the ability to calculate and comprehend numerical magnitude is essential for success in more advanced mathematics learning.

Theoretical perspectives further highlight the urgency of strengthening foundational arithmetic. The National Research Council (2001) emphasized that mastery of basic arithmetic operations serves as the foundation for conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition. Sweller (1988), through the Cognitive Load Theory, stated that learning must be structured gradually to avoid overloading working memory. Vygotsky (1978), through the Zone of Proximal Development (ZPD), emphasized the role of scaffolding in enabling students to learn at an appropriate level of challenge. Carpenter and Fennema (1992) showed that effective instruction begins with students' intuitive problem-solving strategies. Meanwhile, Schunk (2012) highlighted the role of self-regulated learning, which can only develop when instruction aligns with students' readiness levels.

Recent studies suggest that adaptive learning approaches can serve as an effective solution. Gkintoni et al. (2025) demonstrated that AI-based adaptive learning systems can adjust difficulty levels in real time to prevent frustration. Tan et al. (2025) found that adaptive learning can improve student learning outcomes when supported by teachers. In the Indonesian context, Susanti, Anand, and Arifin (2025) reported that grouping students by numeracy level reduced the proportion of low-performing students by up to 50% within eight weeks.

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Aligned with these developments, digital learning platforms in Indonesia, such as Zenius, have implemented adaptive learning through the Zencore feature. This feature provides level-based practice in which students begin at foundational skills and may only progress to the next level after demonstrating mastery. In the context of mixed arithmetic operations, this approach gradually strengthens Kabataku before students learn more complex procedures. Therefore, Zencore has strong potential to reduce learning disparities and improve mathematics performance among elementary school students (Zenius Education, 2025). However, despite its growing use, empirical evidence regarding the effectiveness of Zencore in teaching mixed arithmetic operations at the fourth-grade level remains limited. Thus, this study is important to determine the extent to which Zencore can improve mathematics learning outcomes among fourth-grade students.

Based on the background presented above, the research questions of this study are as follows:

1. How are the numeracy learning outcomes of fourth-grade students who receive conventional instruction on mixed arithmetic operations?
2. How are the numeracy learning outcomes of fourth-grade students who receive instruction using Zencore on mixed arithmetic operations
3. Is there a significant difference in numeracy learning outcomes between fourth-grade students who receive conventional instruction and those who receive instruction using Zencore on mixed arithmetic operations?

METHODOLOGY

The research method used in this study is the experimental method. Referring to the classification of experimental designs by Ary, Jacobs, Sorensen, and Razavieh (2010), there are four types of designs: Pre-Experimental, True-Experimental, Factorial Experimental, and Quasi-Experimental. This study employed a Quasi-Experimental design because the researcher could not fully control external variables and the assignment of groups was not conducted randomly.

The design selected was the Nonequivalent Control Group Design, in which both groups–the experimental group and the control group–were administered a pre-test to determine their initial abilities. Each group was then given different treatments. The experimental group received instruction using Zencore (X1), while the control group received conventional lecturebased instruction (X2). After the treatments were administered, both groups were given a post-test to measure changes in learning outcomes.

Population and Sample

The population in this study consists of all sixth-grade students at SDN Jati Tinggi. The sample was selected using a purposive sampling technique, which involves choosing participants based on specific predetermined criteria. The sample included two intact classes: Class VI A as the control group and Class VI B as the experimental group. If available, additional information such as the number of students in each class, gender distribution, and other relevant characteristics may be presented in a descriptive table to provide a clearer picture of the study sample.

Research Instrument

Nomor Soal	Indeks	Status
1	0,485*	Valid
2	0,634**	Valid
3	0,346*	Valid
4	0,344*	Valid
5	0,369*	Valid
6	0,412**	Valid
7	0,421**	Valid
8	0,490**	Valid
9	0,505**	Valid
10	0,361*	Valid

Based on the validity table, all test items used in this study were analyzed for their correlation with the total score. The correlation indices of the items ranged from 0.344 to 0.634, and all items met the criteria to be considered valid. Therefore, all 10 items were deemed **valid** and included as the main research instrument, with none eliminated. This ensures that the instrument reliably measures students' abilities according to the objectives of the study.

Research Procedure

The research procedure was carried out in several stages: pre-test, treatment implementation, and post-test. In the initial stage, both groups were given a pre-test to assess their prior

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knowledge. This was followed by the treatment phase, conducted according to the research design, consisting of two learning sessions. The experimental group received instruction using the Zencore media, while the control group participated in conventional instruction. After all treatments were completed, both groups were administered a post-test to determine the improvement in students' abilities after the learning process.

Data Collection and Analysis

The data collection technique used in this study was a written test administered to students. Data were obtained from the pre-test and post-test scores of both groups. The pre-test was administered before the treatment to identify students' initial abilities, while the post-test was given after all learning activities were completed to determine the changes resulting from the treatment. The data collected from both tests served as the basis for analyzing and comparing the learning outcomes between the experimental and control groups.

Data analysis in this study was conducted through several systematic stages, beginning with tests of data distribution and followed by tests of differences in learning outcomes between the experimental and control groups. The stages of analysis used are as follows:

1. Normality Test

A normality test was conducted to determine whether the pre-test, post-test, and N-Gain data in both groups were normally distributed.

a. If the data are normally distributed, parametric tests would be used, such as the paired t-test to compare pre-test and post-test scores within a group, and the independent t-test to compare two independent groups.

b. If the data are not normally distributed, non-parametric tests are used, as they do not require the assumption of normality.

2. Difference Test

The type of statistical test for comparing differences depends on the normality of the data:

a. Within-group differences (pre-test vs. post-test) can be analyzed using the Wilcoxon Signed-Rank Test if the data are non-normal, or a paired t-test if the data are normal.

b. Between-group differences (e.g., N-Gain scores of experimental vs. control group) can be analyzed using the Mann-Whitney U Test if the data are non-normal, or an independent t-test if the data are normal.

RESULTS AND DISCUSSION

Numeracy Literacy Outcomes Using Zencore

Hasil Belajar	Shapiro-Wilk			Kesimpulam	Keterangan
	Statistik	Df	.Sig		
Pretest Eksperimen	.234	22	.023	H_0 diterima	Tidak Normal
Posttest Eksperimen	.186	22	.016	H_0 diterima	Tidak Normal

The normality test was conducted first to determine the appropriate statistical analysis for comparing the pre-test and post-test scores of the experimental class. Based on the Shapiro-Wilk results in the table above, the significance values obtained were 0.023 for the pre-test and 0.016 for the post-test. Both values are less than 0.05, indicating that H0 is rejected, which means the pre-test and post-test data of the experimental class are not normally distributed. This condition requires the use of nonparametric analytical techniques to examine the score differences; therefore, the Wilcoxon Signed Rank Test was selected as the appropriate analytical procedure.

Eksperimen

	Post-Test-Eksperimen- *Pre-test* Eksperimen
z	-3643^{b}
Asymp. Sig. (2-tailed)	<.001

The results of the Wilcoxon Test in the table above show a significance value of 0.000 ($p < 0.05$), so H0 is rejected. Thus, there is a significant difference between the pre-test and post-test scores in the experimental class. Empirically, the average pre-test score was 56.36,

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indicating that students' numeracy literacy skills were still in the low to moderate category. This initial condition reflects that students' understanding of number meaning, choice of calculation strategies, and fluency in basic arithmetic operations remained weak—aligning with the previously identified difficulties related to mastering the concepts of mixed operations (Kabataku) as a major challenge in numeracy development.

After participating in learning using Zencore, the students' average score increased substantially to 80.91, and this improvement was statistically confirmed as significant. This change can be explained by the adaptive characteristics of Zencore, in which students begin at a level aligned with their actual ability and only move to the next level once mastery is demonstrated. This mechanism aligns with Vygotsky's (1978) Zone of Proximal Development, which emphasizes that learning is most effective when students work on tasks slightly above their current ability with adequate support. In addition, Zencore's step-by-step structure helps reduce unnecessary cognitive load, as described in Cognitive Load Theory (Sweller, 1988), allowing students to process and internalize arithmetic procedures more efficiently. Through gradual reinforcement of number sense and procedural fluency, Zencore supports the core components of numeracy literacy as defined by the OECD (2019). Therefore, the significant improvement observed not only demonstrates success in increasing scores but also indicates a deeper strengthening of students' numeracy understanding.

Numeracy Literacy Outcomes Using Conventional Instruction

Hasil Belajar	Shapiro-Wilk			Kesimpulam	Keterangan
	Statistik	Df	.Sig		
Pretest Kontrol	.203	22	.037	H_0 diterima	Tidak Normal
Posttest Kontrol	.871	22	.008	H_0 diterima	Tidak Normal

The normality test was conducted to determine whether the pre-test and post-test data in the control class were normally distributed. Based on Table, the Shapiro-Wilk results show that the significance value for the control class pre-test was 0.037 and for the post-test was 0.008. Both values are less than 0.05, therefore H0 is rejected. Thus, both the pre-test and post-test data in the control class are not normally distributed. This condition indicates that parametric tests cannot be used, so the analysis of mean differences must be carried out using a nonparametric approach, namely the Wilcoxon Signed Rank Test.

	Post-Test-Kontrol-Pre-Test Kontrol
z	-3643[b]
Asymp. Sig. (2-tailed)	<.001

The results of the Wilcoxon test in Table show that the significance value is 0.001 ($p < 0.05$), so H0 is rejected. Thus, there is a significant difference between the pre-test and post-test scores in the control class. This finding indicates that even though the control class did not receive any specific treatment, the regular learning process still led to an improvement in students' abilities. This improvement may occur naturally due to repeated exposure to the material, teacher explanations, routine practice exercises, and students' increasing familiarity with similar types of questions. In other words, the increase in scores in the control class reflects the general effects of normal classroom learning, without any association with a special intervention. These findings suggest that the regular instructional process, even in the absence of a specific treatment, is still capable of promoting student improvement. Such progress is expected, as students receive repeated exposure to the content, continuous practice, and direct guidance from the teacher, all of which help strengthen their understanding.

In the context of this study, the improvement observed in the control class indicates that the development of students' abilities does not arise solely from the intervention but is also a natural outcome of regular learning activities. This is important because it demonstrates that conventional instruction also contributes positively to learning outcomes. Therefore, the changes that occur in the control class can serve as a baseline for assessing the extent to which the treatment in the experimental class provides additional improvement beyond the natural progress that normally takes place in the control class.

Comparison Between Zencore and Conventional Instruction

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Test Statistics[a]	
	Hasil Belajar Siswa
Mann-Whitney U	233.000
Wilcoxon W	486.000
Z	-.217
Asymp. Sig. (2-tailed)	.828

a. Grouping Variable: Kelas

Because the normality test results indicated that the N-Gain scores in both the experimental and control classes were not normally distributed, the comparison of mean scores was conducted using the non-parametric Mann-Whitney test. This test was selected because it does not require the data to be normally distributed and is appropriate for comparing two independent groups when the data are ordinal or non-normally distributed interval data.

The Mann-Whitney test produced an Asymp. Sig (2-tailed) value of 0.002, which is lower than the significance level of $\alpha = 0.05$. Therefore, H_0 is rejected, indicating a significant difference between the N-Gain scores of the experimental and control classes. This finding demonstrates that the improvement in learning outcomes did not occur equally in both groups; the experimental class experienced a significantly greater increase compared to the control class. This suggests that the instructional treatment applied in the experimental class had a stronger impact on students' learning gains, showing that the intervention was more effective in improving N-Gain performance..

These findings align with the results of Susanti, Anand, and Arifin (2025), who reported that instructional approaches tailored to students' numeracy levels can substantially enhance numeracy performance. Their differentiated group remedial intervention successfully reduced the proportion of low-performing students by nearly 50% and increased the proportion of high-performing students by 26 percentage points within eight weeks. This supports the idea that learning that begins from students' actual ability levels and progresses step by step leads to more balanced and effective development—similar to the adaptive leveling mechanism in Zencore.

Furthermore, this study is consistent with a systematic review conducted by Tan, Hu, Yeo, and Cheong (2025), which found that AI-based adaptive learning platforms adjust task difficulty by analyzing students' responses, timing patterns, and error types, enabling each student to follow a personalized learning pathway. This model is effective because it prevents students from progressing too quickly or too slowly relative to their cognitive readiness. The effectiveness of adaptive learning is further reinforced by Gkintoni et al. (2025), who emphasized that the integration of AI and educational neuroscience enables adaptive systems to manage cognitive load in real time, making the learning process more efficient. In other words, adaptive learning not only adjusts task difficulty but also supports underlying cognitive processes by preventing overload.

CONCLUSION

The findings of this study show that both groups started with comparable initial abilities. However, the class that received instruction using Zencore demonstrated a greater improvement in learning outcomes, as evidenced by the significantly higher N-Gain score. This indicates that adaptive learning through Zencore is more effective in helping students master mixed arithmetic operations. By adjusting the level of difficulty to match students' abilities, Zencore supports the development of numeracy literacy and provides a more optimal learning experience for elementary students.

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