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Integrating Japanese Line Method: A tool for multiplication in third grade in the context of Philippine curriculum

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ABSTRACT

This study introduced a novel multiplication method which integrates the Japanese Line Method (JLM) within the framework of the Philippine curriculum to help students who are struggling with the traditional approach particularly when multiplying multi-digit numbers. It examined the effectiveness of Japanese Line method as an innovative approach to teaching multiplication to third-grade students at San Rafael Integrated School at San Rafael, Cateel, Davao Oriental, during the 2023-2024 academic year. Using a quasi-experimental design, the research compared two pre-existing groups: a control group of 30 students who received traditional multiplication instruction and an experimental group of 30 students who were taught using the Japanese Line Method. Pre-test results indicated that baseline proficiency levels were comparable across both groups, with each group falling below the "Satisfactory" threshold established by the K-12 grading system. Statistical analysis confirmed that there were no significant differences between the groups at the pre-test stage. However, post-test results showed a substantial improvement in the experimental group's performance, with 91.18% achieving an "Outstanding" grade, compared to 79.08% in the control group. This difference was statistically significant, as indicated by a t-value of -8.252 and a p-value of 0.000. These findings suggest that the Japanese Line Method is a significantly more effective approach than traditional methods in enhancing multiplication proficiency among third-grade students within the Philippine educational context.

Keywords: Japanese line method, long multiplication method, third grade, Philippine curriculum, PISA

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INTRODUCTION

Grade 3 students often encounter significant challenges in mastering multiplication, a fundamental mathematical operation that serves as the foundation for more advanced concepts in mathematics (Mills, 2019; Mahmud and Rahim, 2023). The expectation that students memorize multiplication facts up to 12x12 can be overwhelming, particularly for those who struggle with memorization (Boaler et al., 2015).

The 2019 Trends in International Mathematics and Science Study (TIMSS) shows that Filipino students perform below their international peers in mathematics. The Philippines scored 297 points, ranking lowest among the 58 countries participating in the study (OECD, 2019). Similar findings emerged from the 2018 Program for International Student Assessment (PISA), where the Philippines ranked second-lowest in mathematics among the 79 participating countries. The Department of Education acknowledged these results, attributing them to the poor performance of learners in the National Achievement Test.

According to Thevenot (2023), Inayat et al. (2023), and Davis (2023), one of the primary challenges in teaching multiplication is the complexity involved in its various representations, such as repeated addition, arrays, and word problems. Students often need help understanding the underlying concept of multiplication, which impacts their problem-solving abilities (Nesher, 2020). Moreover, applying multiplication to real-world contexts remains difficult for some students (Flores and Hinton, 2019). Contributing factors to these difficulties include a weak understanding of place value (Baccaglini-Frank et al., 2023), limited math vocabulary (Xin et al., 2023), and lack of motivation (Acharya, 2017). Insufficient understanding of place value impedes students' ability to comprehend problems (Mohyuddin and Khalil, 2016), while limited math vocabulary makes it difficult to follow instructions (Riccomini et al., 2015). Furthermore, motivational issues may arise from previous negative experiences or lack of adequate support (Jay et al., 2018; Bock et al., 2023).

Teaching long multiplication, a traditional method, presents significant challenges due to its time-consuming nature and reliance on a step-by-step approach, as highlighted by Engvall et al. (2020). This process can be particularly error-prone for Grade 3 students, especially those who struggle to track multiple steps or need help with fundamental arithmetic operations. The inherent complexity of this method can hinder the learning process for students who need additional support with basic mathematical concepts (Baral et al., 2021; Chinn, 2020). However, alternative algorithms offer students various multiplication methods, some of which may be more intuitive and easier to master than traditional techniques. Students sometimes prefer these alternative approaches for their simplicity and accessibility. One of these approaches is the Japanese multiplication method (Delbert, 2020, cited by Abari, 2022).

The Japanese multiplication or Japanese Line method is a geometric-based multiplication method invented by Professor Rikitarol in 1900 (Garain and Kumar, 2018). It is a method that allows students to solve multiplication problems by drawing lines that form a diagonal pattern, and the number of intersections near each vertex of a diamond is then counted in a particular order to obtain a solution (Vreken, 2017). It can be extended to handle larger numbers by creating bigger diamonds and using different-colored lines for zeros. In some cases, carrying is needed during the final addition steps (Abari, 2022). For instance, we want to multiply 22 by 13. Using the Japanese Line method, the multiplicand 22 will be drawn horizontally. The first two must be drawn at the top, while the second 2 will be drawn at the bottom. Multiplier 13, on the other hand, must be drawn vertically, where number 1 is at the left, and number 3 is at the right corner. The student can get an accurate result by counting the intersections based on the place value.

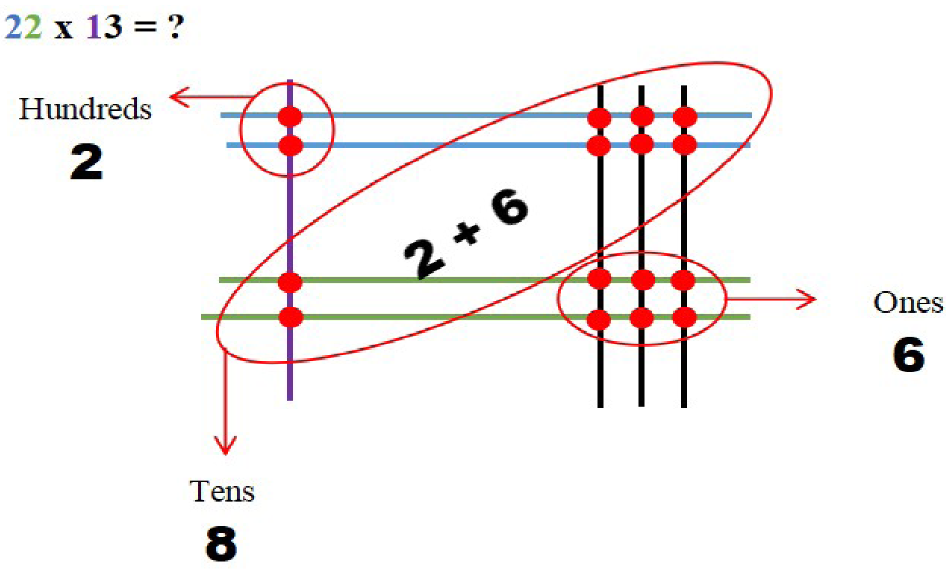

Figure 1. The Japanese Line method of multiplication.

As shown above (Figure 1), 22 x 13 is equal to 286. This visual method is very valuable in teaching the basis of multiplication to children (Abari, 2022). It enhances understanding, accuracy, and efficiency, especially for students struggling with the traditional approach. Studies have shown that the JLM can help students develop a deeper understanding of mathematical concepts, improve their problem-solving skills, and increase their overall achievement in mathematics. In addition to its academic benefits, the JLM has also been shown to have positive social and emotional effects on students. (Shinno and Mizoguchi, 2021). Students taught using the JLM are more likely to be engaged in learning, motivated to succeed, and confident in their abilities (Yu et al., 2022). The JLM also helps to create a positive and supportive learning environment in which students feel comfortable taking risks and asking questions (Kshetree et al., 2021).

This multiplication method allows students to engage in active, hands-on learning, constructing knowledge through exploration and reflective thinking, principles aligned with Piaget's Constructivism Theory. Students physically draw lines to represent the numbers being multiplied, actively manipulating the material to visualize the concept of multiplication. This tactile approach makes abstract mathematical operations more concrete and accessible (Piaget, 1952; Clements and Sarama, 2007). This method allows students to explore multiplication visually and spatially, encouraging discovery and a deeper understanding of the operation beyond simple rote memorization (Battista, 1999). Furthermore, the method fosters reflective thinking, as students can compare and contrast the Japanese Line Method with traditional multiplication algorithms, prompting them to ask questions like "How does this method help me understand multiplication better?" This reflective process enhances their cognitive development and reinforces their conceptual grasp of multiplication (Schön, 1983).

With that, the researchers selected this study based on its empirical nature during their FS 100, where numerous students still need help understanding the concept of multiplication and following the steps of the long method despite being in the intermediate grade. Knowing that the foundation of learning multiplication starts at the third level in the elementary grade, this study aimed to offer valuable insights into the efficacy of the Japanese Line method in improving multiplication among Grade 3 students at San Rafel Integrated School.

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METHODOLOGY

Research locale

The study was conducted at San Rafael Integrated School, Proper, San Rafael, Cateel, Davao Oriental, a critical educational institution within Cateel District 2 (Figure 2). The school was selected as the research site based on the researchers' empirical observations during their teaching practicum and assistantship in FS 100 and FS 101, highlighting the difficulties among students in understanding multiplication concepts, which motivated the study.

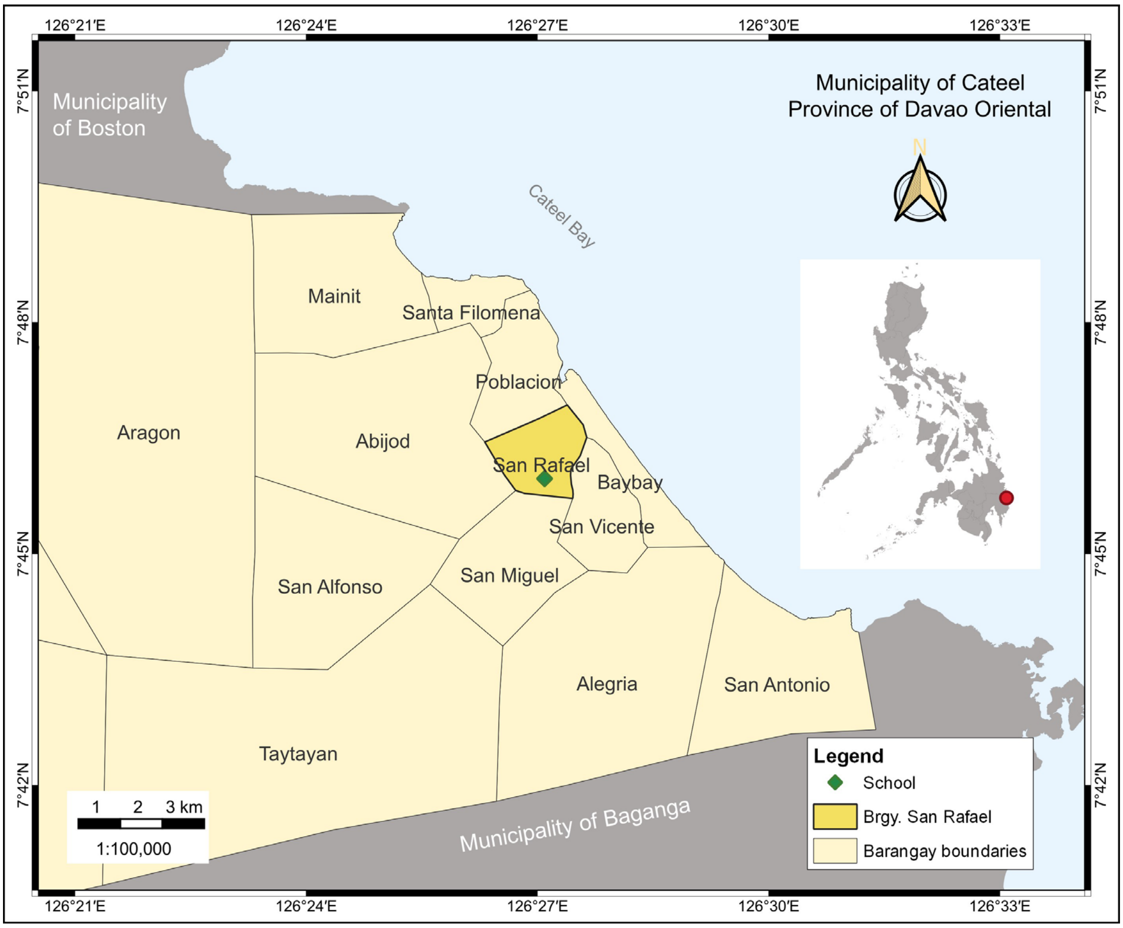

Figure 2. Map showing San Rafael Integrated School (SRIS).

Research design

The quasi-experiments will likely be conducted in field settings where random assignment is difficult or impossible. They are often conducted to evaluate the effectiveness of a treatment—perhaps a type of psychotherapy or an educational intervention (Paul et al., 2015). A quasi-experimental research design is appropriate for this study as it involved pre-existing groups (the control and experimental groups) that could not be randomly assigned.

Research instrument

The researchers employed a 20-item achievement test to assess students' ability to multiply 2-digit numbers by 2-digit numbers, incorporating factors and word problems. This test was structured to facilitate the recall of multiplication concepts and the analysis and practical application of these concepts. The selection of 20 items, rather than 10 or 30, was based on the results of a pilot test, which demonstrated that 20 of the original 30 questions met the criteria for effectiveness and reliability, while the other ten were removed due to insufficient validity. This test was validated and tested for reliability to ensure it accurately measured the respondents' learning outcomes through initial and final evaluations.

Data collection

Prior to data collection, the researchers obtained ethical clearance from the Research Ethics Office (REO) at Davao Oriental State University—Cateel Extension Campus. They developed a questionnaire that underwent validity and reliability testing to ensure its appropriateness for the study. After securing approval from the principal of San Rafael Integrated School, the researchers submitted a formal request to the class advisers to conduct the study and administer the tool to the students in the experimental group.

Figure 3. Conduct of pilot testing of the test-questions at Sta. Felomina Elementary School (A); conduct of pilot testing of the test-questions at Modesto T. Veroy Elementary School (B); conduct of pre-test for the experimental (C); and control group (D); conduct of post-test for the experimental (E); and control group (F).

This study involved two sections of Grade 3 students, each assigned to either a control or an experimental group (Figure 3). This assignment was based on entire sections rather than individual student sampling. To reduce potential biases, a one-coin-toss randomization method was employed. Each section, represented by its adviser, was assigned a number, and a coin flip determined whether the section

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would belong to the experimental or control group. Each section comprised 30 participants, resulting in a total sample size of 60 students. The control group was taught using traditional instructional methods, while the experimental group used the Japanese line method. To prevent cross-learning and ensure the integrity of the study, both sections received instruction simultaneously but separately. This setup ensured that while the control group engaged in quizzes and test practices under the supervision of their assigned researcher, the experimental group participated in similar activities monitored by their respective researcher.

Before the intervention, a pre-test was administered to all respondents to address the potential issue of disproportionate talent distribution between the control and experimental groups. This pre-test helped establish a baseline measure of the student's existing knowledge and skills, ensuring comparability between the groups. Alongside the pre-test, participants received a consent form that requested their permission to be part of the research and allowed them to provide their names optionally; signatures were required to confirm consent. The pre-test data were collected to assess initial proficiency levels, which enabled the researchers to account for any disparities in talent distribution. This step was crucial for the research design, which followed a quasi-experimental approach, allowing for a controlled comparison of the traditional teaching method with the Japanese line method while minimizing bias and ensuring valid results. After administering the pre-test, the data were totaled, tallied, encoded, analyzed, and interpreted to provide insights into the effectiveness of the instructional methods.

During the instructional phase, the control group was taught multiplication using traditional methods, while the experimental group received instruction through the Japanese Line method to enhance their multiplication skills. Following these instructional sessions, both groups were given post-tests to evaluate the effectiveness of the teaching methods and to determine whether the intervention positively impacted the student's ability to multiply 2-digit numbers by 2-digit numbers and 3-digit numbers by 2-digit numbers.

After the intervention, post-test questionnaires were administered to assess the effectiveness of the instructional methods used in the control and experimental groups. The data were then collected, totaled, tallied, encoded, analyzed, and interpreted to conclude the intervention's impact. To address the issue of student absences, make-up sessions were arranged to ensure that all students received the same amount of instruction, maintaining the integrity of the study. The intervention was consistently implemented by assigning specific researchers to monitor and deliver the traditional method to the control group and the Japanese line method to the experimental group, ensuring that the sessions were conducted as planned. To minimize external influences, researchers ensured that other teachers did not provide additional instructional support during the intervention period, helping to isolate the effect of the intervention itself on the student's performance.

Data analysis

Content validity. The content validity of the instrument was confirmed through the use of Aiken's V coefficient, which is based on expert evaluations of the instrument's relevance to the learning goals, its necessity, and the quality of its contents, reaching an impressive value of 0.92, indicating strong validity (Sireci & Bond, 2014).

Reliability. The instrument's reliability was also measured using Cronbach's alpha, achieving a coefficient of 0.86, which shows a high level of consistency for its purpose (Ahdika, 2017).

The K-12 Department of Education grading system was employed to analyze and arrive at a trustworthy and accurate interpretation of the gathered data from the pre-test and post-test questionnaire responses from the experimental and control groups. Mean scores and an independent sample t-test were used to determine and analyze the findings.

Mean. This statistical instrument was used to determine (1) the average of pre-test multiplication test score achievement between the control group and the experimental group and (2) the average of post-test multiplication test score achievement between the control group and the experimental group. The result was interpreted based on the grading scale with its corresponding interpretation:

Table 1. K to 12 grading scale and interpretation.

Grading scale	Interpretation
90-100	Outstanding
85-89	Very Satisfactory
80-84	Satisfactory
75-79	Fairly Satisfactory
75 Below	Did Not Meet Expectations

T-test. This statistical tool was used to (3) determine whether there was a significant difference in the mean scores of pre-test and post-test multiplication test achievement among students between the control group and experimental group.

RESULTS

Pre-Test multiplication test score achievement

This study compared students' multiplication skills in an experimental group (n = 30) and a control group (n = 30) before implementing the Japanese Line Method and the traditional long multiplication method. Both groups underwent a pre-test to assess their baseline multiplication skills, specifically their ability to multiply two-digit numbers by two-digit numbers and three-digit numbers by two-digit numbers. Table 2 shows that the control group had an average pre-test score of 7.93, with a grade percentage of 69.82%. The experimental group had a slightly lower average score of 7.50, with a grade percentage of 68.75%. According to the interpretation of the K–12 grading scale, both groups did not meet expectations.

Table 2. Level of pre-test scores between the control and experimental groups.

Group	Score	SD	$\bar{x}$	Percentage(%)	Remarks
Control	20	2.00	7.93	69.82	Did Not Meet Expectation
Experimental	20	2.21	7.50	68.75	Did Not Meet Expectation

Difference in Pre-Test multiplication test score achievement

Table 3 compares the pre-test scores between the control and experimental groups. The results indicate no significant difference between the groups, as shown by a t-value of -0.797 and a p-value of 0.429.

To control extraneous variables, such as students receiving additional instruction from other teachers, parents, or online resources like YouTube, the researchers ensured that both groups were taught simultaneously using their respective methods. Researchers also monitored classroom activities to prevent outside influence and strictly followed the study protocol to isolate the effect of the traditional and Japanese line methods. This approach minimized the impact of external learning opportunities, ensuring that any observed differences in outcomes could be attributed to the instructional methods used during the intervention.

Table 3. Mean comparison between pre-test scores of control and experimental group.

Group	x̄	SD	*t*-value	*p*-value	Interpretation
Control Experimental	7.50 7.93	2.21 2.00	-0.797	0.429	Pre-test scores between the two groups do not differ significantly

Post-Test multiplication test score achievement

Table 4 demonstrates a significant disparity in post-test scores between the control and experimental groups. Using traditional multiplication methods, the control group achieved an average score of 11.63, with a grade percentage of 79.08%, categorized as "Fairly Satisfactory." In contrast, using the Japanese Line Method, the experimental group achieved a markedly higher average score of 16.47, with a grade percentage of 91.18%, labeled as "Outstanding."

Table 4. Level of post-test scores between the control and experimental groups.

Group	Score	SD	x̄	Percentage (%)	Remarks
Control	20	1.67	11.63	79.08	Fairly Satisfactory
Experimental	20	2.74	16.47	91.18	Outstanding

Difference between Post-Test scores

Table 5 reveals a significant difference in post-test scores between the control and experimental groups. The control group had an average score of 11.63 with a standard deviation of 1.67, while the experimental group had a significantly higher average score of 16.47 with a standard deviation of 2.74. The *t*-value of -8.252 and *p*-value of 0.000 indicate that the score difference is statistically significant.

Table 5. Mean comparison between post-test scores of control and experimental group.

Group	x̄	SD	*t*-value	*p*-value	Interpretation
Control Experimental 0	11.63 16.47	1.67 2.74	-8.252	0.000	Post-test scores between the two groups differ significantly

DISCUSSION

The pre-test scores of the participants in the control group averaged 7.93, with a corresponding grade percentage of 69.8, which suggests that students did not meet expectations. Conversely, the experimental group displayed a slightly lower mean average of 7.50 and a grade percentage of 68.75, similar to the control group's performance in failing to meet the expected standards. Research has indicated that students' proficiency in multiplication can be influenced by various factors such as cognitive abilities (Zaid and Ismail, 2023), prior mathematical knowledge (Niringiyimana and Maniraho, 2023), instructional methods (Langner, 2023), and socio-economic background (Suárez-Pellicioni et al., 2024). These factors can impact students' readiness to grasp multiplication concepts and perform well on assessments (Kaup et al., 2023).

The pre-test scores between the control and experimental groups show no significant difference, as indicated by the t-value of -0.797 and a p-value of 0.429. This suggests no initial variations in the students' knowledge levels before class discussions occur. This result suggests that at the outset of the study, both groups had comparable levels of multiplication proficiency, ensuring that any subsequent differences in performance could be attributed to the instructional methods rather than pre-existing differences in ability. The lack of significant difference aligns with the idea that third-grade students generally face similar challenges in mastering multiplication, such as difficulties with memorization, understanding multiplication concepts, and applying skills to real-world problems (Langner, 2023; Mahmud and Rahim, 2023; Nesher, 2020).

Table 4 demonstrates a significant disparity in multiplication performance between the control and experimental groups. The control group, which utilized traditional multiplication methods, achieved a mean score of 11.63 with a standard deviation of 1.67, translating to a grade percentage of 79.08%, categorized as "Fairly Satisfactory." In contrast, the experimental group instructed using the Japanese Line Method attained a markedly higher mean score of 16.47 with a standard deviation of 2.74, resulting in an impressive grade percentage of 91.18%, labeled as "Outstanding." The lower mean outcomes in the control group highlight significant challenges with traditional multiplication methods, such as the extended multiplication algorithm, which can be time-consuming and mentally exhausting for students (Chinn, 2020; Wankhade et al., 2022). These methods often overwhelm students, especially those struggling with sequential tasks or concentration (Baroody et al., 2016; Sherin and Fuson, 2015), and may not meet the diverse learning needs of students who benefit from more visual or hands-on approaches (Baral et al., 2021; Powell and Nelson, 2017). Additionally, the reliance on rote memorization can hinder deeper understanding for students needing a solid conceptual foundation (Boaler et al., 2015). In contrast, using the Japanese Line Method (JLM), the experimental group achieved a significantly higher mean score, reflecting the method's success in improving multiplication understanding through its visual and hands-on approach (Clements and Sarama, 2007; Foster, 2023). The JLM encourages active exploration and discovery, fostering a deeper conceptual understanding and more efficient problem-solving skills (Bruce et al., 2023; Irvine, 2020). Aligned with Piaget's constructivist theory, the JLM promotes active learning and problem-solving, leading to better student outcomes in multiplication (Bada and Olusegun, 2015; Rabillas et al., 2023).

The findings in Table 5 reveal a significant difference in post-test scores between the control and experimental groups. The control group, which employed traditional multiplication methods, achieved a mean score of 11.63 with a standard deviation of 1.67. In contrast, the experimental group taught using the Japanese Line Method obtained a substantially higher mean score of 16.47, with a more significant standard deviation of 2.74. The calculated t-value of -8.252 and p-value of 0.000 indicate that this difference in scores is statistically significant, highlighting the effectiveness of the Japanese Line Method in improving students' multiplication skills compared to traditional methods. The results highlight the effectiveness of the Japanese Line Method in improving students' multiplication skills compared to traditional methods. The method's visual and hands-on approach likely contributed to the experimental group's superior performance, fostering a deeper conceptual understanding and enhancing problem-solving abilities. The significant t-value indicates that this improvement was not by chance, reinforcing the method's impact. The Japanese Line Method aligns with Piaget's principles of discovery and reflection, supported by Jean Piaget's constructivist theory, which emphasizes learning through active engagement and exploration. The variability in student responses also suggests the importance of considering individual learning styles when implementing innovative teaching methods. Overall, the study underscores the potential of the Japanese Line Method to enhance multiplication skills in third-grade students, demonstrating the application of constructivist principles in modern education.

The study's findings highlight the effectiveness of the Japanese Line Method in enhancing third-grade students' multiplication skills compared to traditional teaching methods, which have significant implications for mathematics education, particularly in teaching multiplication to third-grade students. This method offers a valuable alternative, improving understanding and performance in multiplication and addressing learning gaps in early education (Sunzuma, 2023; Thinwiangthong et al., 2024). Its visual and systematic approach engages students, particularly those struggling with conventional methods, making abstract concepts more concrete (Bakos, 2023; Sianturi and Hurit, 2024). The results suggest that integrating such innovative strategies into the curriculum can boost mathematical competence and educational outcomes (Aguhayon et al., 2023; Bang and Flynn, 2023). The study also recommends professional development for teachers to enhance their instructional techniques and further research on the method's application across age groups and topics (Nguyen, 2023; Kumar and Deák, 2023).

CONCLUSION

The findings of this study highlight the need for alternative multiplication approaches, such as the Japanese Line Method, as traditional multiplication often falls short in effectively addressing students' difficulties with multiplication due to their complexity, particularly when multiplying large numbers (e.g., two-digit by two-digit numbers), due to the inherent complexity of these operations.

Given the low pre-test scores of students in multiplying 2-digit numbers, indicating that they did not meet K-12 grading expectations, it is recommended that teachers conduct remediation sessions to improve retention and understanding. Since no significant difference was observed in the pre-test scores between the control and experimental groups, any intervention should be applied uniformly across all Grade 3 sections. As the control group's post-test results also failed to meet the K-12 standards, innovative strategies may be implemented to enhance student understanding. Additionally, considering the Japanese Line Method's effectiveness in improving multiplication skills, the Department of Education (DepEd) may incorporate this method into teacher seminars or Learning Action Cell (LAC) sessions to ensure proper integration into regular math instruction.

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