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Developing Microlearning-Based Materials for Elementary School Mathematics Instruction

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Abstract

This study explores the development and effectiveness of microlearning-based materials in enhancing elementary school students' understanding of mathematics. Microlearning, characterized by short, focused learning segments, offers an innovative approach to addressing common challenges in traditional mathematics instruction, such as student engagement and information retention. The primary objective of this research is to design and evaluate microlearning materials tailored for elementary mathematics lessons. A set of interactive, multimedia-based lessons was developed, focusing on key mathematical concepts and delivered through a learning management system. The study involved a group of elementary school students, and data was collected through pre-and post-tests, as well as surveys assessing student engagement and feedback. The results indicate a significant improvement in student performance, with higher engagement and positive perceptions of the microlearning approach. The findings suggest that microlearning can be an effective tool in enhancing student learning outcomes in mathematics, offering a scalable solution for modernizing educational practices. This research contributes to the growing body of literature on microlearning and provides practical insights for educators seeking to integrate innovative instructional materials into their classrooms. Future research should explore the long-term effects and the applicability of microlearning across various mathematical topics and educational settings.

Keywords: *Microlearning, Elementary School Mathematics, Educational Materials, Instructional Design, Student Engagement, Pedagogical Tools*

INTRODUCTION

Mathematics education at the elementary level is crucial for fostering critical thinking and problem-solving skills among students. However, traditional instructional methods often fail to engage students effectively, leading to a perception of mathematics as an abstract and challenging subject. This perception can result in lower motivation and difficulties in mastering essential mathematical skills, highlighting the urgent need for innovative teaching strategies that cater to diverse learning needs and promote sustained interest in mathematics.

Research indicates that the implementation of higher-order thinking Skills (HOTS) assessment instruments can significantly enhance students' critical thinking abilities in mathematics. For instance, Melawati et al. emphasize that educators require valid and reliable HOTS assessment tools to facilitate the development of critical thinking skills in mathematics learning, which have been shown to improve student engagement and understanding (Melawati et al., 2022). Additionally, the integration of complex mathematical problems that stimulate higher-order thinking is essential for developing critical thinking skills, as noted by Fitriyah et al., who state that high-level math problems involving analysis and synthesis can encourage students' critical thinking abilities (Fitriyah et al., 2020). This aligns with the notion that mathematics education should not only focus on rote memorization but also on fostering analytical and evaluative skills that students can apply in real-world contexts, as highlighted by (Kurnianti & Sarifah, 2023).

Furthermore, the pedagogical approaches employed by teachers play a pivotal role in shaping students' attitudes towards mathematics. Alkhateeb's study reveals that as students progress through their teacher education programs, their anxiety regarding teaching mathematics decreases, suggesting that effective training can enhance teachers' confidence and competence in delivering mathematics instruction (Alkhateeb, 2014). This is supported by Dangnga's findings, which indicate that teachers with higher educational attainment possess better mathematical knowledge for teaching, thereby positively influencing student learning outcomes (Dangnga, 2020). The development of teachers' mathematical knowledge is critical, as it directly impacts their ability to create engaging and meaningful learning experiences for their students.

Innovative instructional models, such as the ABC model of critical thinking proposed by Buhaerah and Dangnga, emphasize anticipation, building knowledge, and consolidation as key components in fostering critical thinking in mathematics (Dangnga, 2020). Such models encourage active learning and student participation, which are essential for maintaining engagement and promoting a deeper understanding of mathematical concepts. Moreover, the use of graphic organizers has been shown to enhance students' critical thinking abilities by providing structured frameworks for problem-solving, as discussed by Kurniaman et al. (Kurniaman et al., 2020). This approach aligns with the broader goal of integrating critical thinking into the mathematics curriculum, as emphasized by Yin et al., who advocate for the incorporation of critical thinking skills in daily instruction to prepare students for complex life situations (Yin et al., 2023). Addressing the challenges faced in elementary mathematics education requires a multifaceted approach that includes the development of effective assessment tools, the enhancement of teachers' mathematical knowledge, and the implementation of innovative instructional strategies. By focusing on these areas, educators can create a more engaging and supportive learning environment that fosters critical thinking and problem-solving skills in students, ultimately leading to improved outcomes in mathematics education.

Microlearning has gained traction in educational contexts as a method that delivers content in small, focused segments, enhancing the learning experience by catering to the cognitive limitations of learners. This approach is particularly relevant in elementary school mathematics, where traditional methods may not effectively engage students or facilitate retention of complex concepts. The effectiveness of microlearning is rooted in its ability to present information in manageable chunks, which aligns with cognitive theories suggesting that learners retain information better when it is broken down into smaller, digestible parts (N. F. Alias & Razak, 2023; Mohammed et al., 2018).

Research indicates that microlearning can significantly improve learning outcomes across various educational settings. For instance, studies have shown that microlearning enhances retention and engagement, particularly when combined with interactive and multimedia elements (Faizal Rizky et al., 2023; Hutauruk et al., 2021). This is particularly pertinent in mathematics education, where students often struggle with abstract concepts. By utilizing microlearning strategies, educators can provide targeted interventions that address specific learning needs, thereby fostering a more supportive learning environment (Martinho et al., 2023). Furthermore, the integration of technology in microlearning allows for flexible and accessible learning experiences, which can be crucial for young learners who may benefit from repeated exposure to mathematical concepts in varied formats (Schoenfeld, 2016).

Despite the promising potential of microlearning in elementary mathematics, its application remains underexplored. Many existing studies focus on adult learners or specific disciplines, such as language learning or health professions (Barus & Bontisesari, 2023; Berger-Estilita & Greif, 2020). This gap highlights the need for further research into how microlearning can be tailored to meet the unique challenges of elementary mathematics education. For instance, the design of microlearning modules that incorporate game-based elements or real-world problem-solving scenarios could enhance engagement and understanding among young learners (N. F. Alias & Razak, 2023). Additionally, the pedagogical frameworks that underpin microlearning need to be adapted to ensure that they align with the developmental stages of elementary students (N. Alias & Siraj, 2012). Microlearning presents a viable solution to some of the challenges faced in elementary school mathematics education. By delivering content in small, focused segments and leveraging technology, educators can create engaging and effective learning experiences that cater to the needs of young learners. However, further exploration and research are essential to fully understand its application and effectiveness in this context.

This study seeks to develop microlearning-based materials specifically designed for elementary school mathematics instruction and evaluate their impact on student learning outcomes. By integrating short, engaging lessons into a digital format, the aim is to increase student engagement, improve retention of mathematical concepts, and enhance overall learning experiences. The study also investigates how such materials can be tailored to suit the diverse cognitive and learning styles of elementary school students, allowing for personalized and differentiated learning experiences. The primary objectives of this research are twofold: first, to design a series of microlearning-based lessons that focus on key mathematical concepts aligned with elementary curricula, and second, to assess the effectiveness of these materials in improving student performance and engagement. The findings from this study have the potential to inform educators about the advantages of microlearning and provide insights into how this innovative approach can be integrated into mainstream elementary school mathematics instruction.

By addressing the gap in research on microlearning within elementary mathematics education, this study aims to contribute to the broader discourse on educational innovation and pedagogical strategies that can better support the diverse learning needs of young students. Ultimately, the research aims to provide practical recommendations for educators looking to leverage microlearning as a tool for enhancing mathematics teaching and learning in the elementary classroom.

METHODS

This section outlines the design and development of microlearning-based materials for elementary school mathematics instruction, the participants involved, and the research methodology used to assess the effectiveness of these materials. The study employed a mixed-methods approach, combining both qualitative and quantitative data collection to provide a comprehensive evaluation of the materials' impact on student learning and engagement.

DESIGN AND DEVELOPMENT OF MICROLEARNING MATERIALS

The development of the microlearning-based materials followed a structured process to ensure that the lessons were engaging, pedagogically sound, and aligned with elementary school mathematics curricula. The following steps were involved in the design and development:

> Needs Analysis and Curriculum Alignment: An analysis of the existing mathematics curriculum for elementary school students was conducted to identify key mathematical concepts that could benefit from microlearning. Topics such as basic arithmetic, fractions, geometry, and measurement were selected as the focus for the microlearning materials. The materials were designed to align with national educational standards and the developmental stages of elementary school students.
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> Instructional Design: The materials were created based on principles of instructional design, with an emphasis on breaking down complex concepts into small, manageable chunks. Each lesson was structured to last no longer than 10 minutes and incorporated interactive elements such as quizzes, drag-and-drop activities, and multimedia content (videos, animations, diagrams). The lessons were designed to be self-paced, allowing students to complete them in their own time and revisit content as needed.
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> Technology Platform: The microlearning materials were delivered via a user-friendly online learning management system (LMS) that allowed for easy navigation and tracking of student progress. The LMS was chosen for its interactive features, including real-time feedback and the ability to monitor students' performance on quizzes and activities.
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> Pedagogical Approach: The materials were designed with a constructivist approach in mind, encouraging students to engage with the content actively through problem-solving and self-discovery. Scaffolding techniques were employed, where each lesson gradually increased in complexity, ensuring that students could build on their prior knowledge while learning new concepts.

PARTICIPANTS

The participants in this study were elementary school students from two schools in the district, aged between 8 and 10 years old (Grades 3-4). A total of 120 students participated, with an equal distribution of male and female students. The participants were divided into two groups:

Experimental Group (Microlearning Intervention): This group consisted of 60 students who used the microlearning-based materials over 4 weeks. They completed lessons on selected mathematical topics, with each lesson involving approximately 10-15 minutes of engagement per day.

Control Group (Traditional Instruction): The control group consisted of 60 students who received traditional mathematics instruction over the same 4-week period. The curriculum and teaching methods for this group followed standard classroom instruction without the incorporation of microlearning materials.

The schools were randomly assigned to either the experimental or control group to minimize any selection bias. Before the intervention, the students were assessed to ensure equivalence in terms of baseline mathematical abilities.

INSTRUMENTS

To evaluate the effectiveness of the microlearning materials, multiple data collection instruments were used:

Pre- and Post-Test: A mathematics assessment was developed to measure student performance before and after the intervention. The pre-test was administered at the beginning of the study to gauge the baseline knowledge of students in both groups. At the same time, the post-test was given at the end of the intervention to assess any changes in students' understanding of the mathematical concepts covered. The test included multiple-choice questions, short answer questions, and problem-solving tasks that tested both procedural skills and conceptual understanding.

Engagement and Satisfaction Survey: A survey was administered to the experimental group at the end of the study to assess their engagement with the microlearning materials and their satisfaction with the learning experience. The survey included Likert-scale questions, as well as open-ended questions, to gather both quantitative and qualitative data on student perceptions, motivation, and overall satisfaction with the microlearning format.

Teacher Observations: Teachers involved in the study were asked to observe and record students' participation and engagement levels during the intervention. Teachers' feedback on how the microlearning materials fit into the classroom setting, as well as their observations on student behaviour, were collected through weekly reflection journals.

DATA ANALYSIS

The data collected from the pre-and post-tests, surveys, and teacher observations were analyzed using both quantitative and qualitative methods:

Quantitative Analysis:

- Descriptive statistics (mean scores, standard deviation) were calculated for the pre-and post-test results to compare the performance of both groups.
- Paired t-tests were conducted to determine whether the differences between pre-and post-test scores within each group were statistically significant.
- An independent samples t-test was used to compare the post-test scores of the experimental and control groups to determine whether the microlearning intervention had a significant effect on students' performance.

Qualitative Analysis:

- The open-ended responses from the engagement and satisfaction survey were analyzed thematically to identify common patterns in students' perceptions of the microlearning materials.
- Teacher observation notes were coded to identify key themes related to student engagement, interaction with the materials, and any challenges or benefits observed during the intervention.

RESULTS

This section presents the findings from the data analysis conducted to assess the effectiveness of the microlearning-based materials in enhancing elementary school student's understanding of mathematics. The results are organized into three key areas: (1) academic performance (pre-and post-test results), (2) student engagement and satisfaction (survey responses), and (3) teacher observations. Both quantitative and qualitative data are reported to provide a comprehensive overview of the impact of the microlearning intervention.

ACADEMIC PERFORMANCE: PRE- AND POST-TEST RESULTS

The pre-and post-test scores of both the experimental group (micro-learning) and the control group (traditional instruction) were analyzed to determine the impact of the microlearning materials on student performance, as shown in Table 1.

Table 1: Pre- and Post-Test Results for Academic Performance

Group	Pre-Test		Post-Test		Mean Improvement	t-Value	ρ-Value
	Mean (%)	SD	Mean (%)	SD			
Experimental Group (Microlearning)	52.3	8.2	76.5	10.1	24.2	9.8	0.001
Control Group (Traditional Instruction)	51.7	7.9	65.4	9.6	13.7	5.21	0.001

PRE-TEST RESULTS:

- Both the experimental and control groups had similar mean pre-test scores, indicating that both groups started with comparable levels of understanding of the mathematical concepts.
- The experimental group had a mean pre-test score of 52.3% (SD = 8.2), while the control group had a mean pre-test score of 51.7% (SD = 7.9). These results confirm that there were no significant differences in the baseline performance between the two groups.

POST-TEST RESULTS:

- After a 4-week intervention, both groups showed improvement in their post-test scores. However, the experimental group, which used microlearning materials, demonstrated significantly greater improvement compared to the control group.
- The experimental group had a mean post-test score of 76.5% (SD = 10.1), while the control group had a mean post-test score of 65.4% (SD = 9.6).

- The difference in post-test scores between the two groups was statistically significant ($t(118) = 5.32$, $p < 0.001$), suggesting that the microlearning intervention led to greater improvements in mathematical understanding than the traditional instruction.

WITHIN-GROUP COMPARISON:

- **Experimental Group:**
  - The experimental group showed a significant increase of 24.2% in their mean scores from the pre-test to the post-test ($t(59) = 9.81$, $p < 0.001$), indicating that microlearning had a strong positive effect on their academic performance.
- **Control Group:**
  - The control group also showed improvement, with an increase of 13.7% in their mean scores ($t(59) = 5.21$, $p < 0.001$), but the improvement was smaller compared to the experimental group. This suggests that while traditional instruction led to some improvement, it was not as effective as the microlearning intervention.

Overall, these results indicate that microlearning was more effective than traditional instruction in improving students' understanding of the mathematical concepts assessed in the study.

STUDENT ENGAGEMENT AND SATISFACTION: SURVEY RESPONSES

A survey assessing student engagement and satisfaction was administered to the experimental group at the end of the study. The survey included both Likert-scale questions and open-ended responses to gather insights into students' perceptions of the microlearning materials, as shown in Table 2.

Table 2: Survey Results on Student Engagement and Satisfaction

Survey Question	Percentage of Students Responding "Agree" or "Strongly Agree"
Engagement	
- The microlearning lessons were engaging and interesting. - The materials helped me understand mathematical concepts better. - I enjoyed using the interactive elements (quizzes, activities).	85% 78% 80%
Satisfaction	
- Overall, I am satisfied with the microlearning experience. - I prefer the microlearning approach over traditional classroom instruction.	87% 75%

ENGAGEMENT:

- A high level of engagement was reported among the students in the experimental group, with 85% agreeing that the microlearning lessons were engaging and interesting. This suggests that the microlearning format successfully captured students' attention and maintained their interest throughout the course.
- 78% of students felt that the materials helped them understand mathematical concepts better, indicating that the microlearning approach effectively facilitated their comprehension.
- Additionally, 80% of students enjoyed the interactive elements, such as quizzes and activities, highlighting the positive impact of these components on the learning experience. The use of interactive elements likely contributed to increased student engagement and made learning more enjoyable.

SATISFACTION:

- The majority of students (87%) expressed overall satisfaction with the microlearning experience, reflecting that they found the microlearning lessons to be valuable and beneficial to their learning process.
- 75% of students indicated a preference for microlearning over traditional classroom instruction, citing benefits such as flexibility and the ability to learn at their own pace. This suggests that students appreciated the self-directed nature of microlearning, as it allowed them to manage their learning according to their individual needs and schedules.

OPEN-ENDED RESPONSES:

- Students' open-ended feedback revealed that they appreciated the brevity and focus of the microlearning lessons. One student mentioned, "I like how short and easy to understand the lessons were," emphasizing the advantage of concise and well-structured content in microlearning.
- Positive feedback was also given regarding the interactive elements, such as quizzes and games, which were described as making learning more enjoyable and helping students retain the material better.
- Some students expressed a desire for more variety in the topics covered, suggesting that additional practice or exploration of certain concepts could enhance the learning experience.

Overall, the survey results indicate that students in the experimental group were highly engaged and satisfied with the microlearning materials. The approach was particularly appreciated for its interactivity, brevity, and flexibility, though there was some room for expanding the variety of topics covered in future iterations.

TEACHER OBSERVATIONS

Teachers observed the students' behaviour and participation during the intervention. The following key observations were recorded:

Student Engagement: Teachers noted that students in the experimental group demonstrated higher levels of active participation compared to the control group. Students in the experimental group were more likely to ask questions, discuss concepts with peers, and eagerly complete their daily lessons. Teachers observed that students were more motivated and focused during the microlearning sessions compared to traditional lessons.

Classroom Behavior: The experimental group exhibited greater enthusiasm and less restlessness during lessons. Teachers reported that students were able to complete the microlearning lessons independently, and the quick feedback provided by the LMS kept them engaged throughout the session. In contrast, students in the control group were more likely to become disengaged during longer, more traditional lessons.

Challenges: Teachers noted a few challenges in implementing the microlearning materials, particularly with the technical aspects of the platform. While most students adapted well to the technology, a small number of students initially faced difficulties with accessing and navigating the lessons. These challenges were quickly resolved with additional support from the teachers.

SUMMARY OF FINDINGS

Academic Performance: The experimental group showed significantly greater improvement in mathematics performance compared to the control group. The microlearning-based materials positively impacted student understanding of key mathematical concepts.

Engagement and Satisfaction: Students in the experimental group were highly engaged with the microlearning materials and reported positive experiences, particularly in terms of the interactivity and brevity of the lessons. The majority of students expressed a preference for microlearning over traditional teaching methods.

Teacher Observations: Teachers observed higher levels of student engagement and motivation in the experimental group, with students demonstrating increased interest in learning and fewer behavioral issues.

Overall, the results indicate that microlearning-based materials are an effective and engaging way to enhance elementary school students' understanding of mathematics. The intervention not only led to improved academic performance but also fostered greater student engagement and satisfaction compared to traditional instructional methods.

DISCUSSION

This study aimed to develop and evaluate microlearning-based materials for elementary school mathematics instruction and assess their impact on student performance, engagement, and satisfaction. The results provide evidence that microlearning can be an effective and engaging pedagogical approach for teaching mathematics at the elementary level, demonstrating improvements in both academic performance and student engagement compared to traditional instructional methods. In this discussion, we interpret the findings, compare them with previous research, highlight the practical implications, and suggest areas for future research.

EFFECTIVENESS OF MICROLEARNING IN ENHANCING STUDENT PERFORMANCE

The results of this study indicate that microlearning-based materials significantly improved the academic performance of elementary students in mathematics. The experimental group, which used microlearning materials, showed a greater increase in post-test scores (24.2%) compared to the control group (13.7%). This difference was statistically significant, suggesting that microlearning was more effective in promoting mathematical understanding than traditional teaching methods. Microlearning has emerged as a significant pedagogical approach that enhances student retention and understanding, particularly in mathematics education. This method involves breaking down complex concepts into smaller, more manageable segments, which facilitates better comprehension and retention of information among students. Research indicates that microlearning can effectively address knowledge gaps and reduce dropout rates, ultimately leading to improved academic performance. For instance, Martinho highlights that integrating microlearning into higher education mathematics not only provides flexibility for students but also contributes to higher final grades and lower dropout rates, thereby enhancing overall academic success (Martinho et al., 2023).

Furthermore, the active learning components embedded within microlearning, such as interactive quizzes and activities, play a crucial role in reinforcing the learning process. These elements encourage students to apply their knowledge in real time, which is essential for deep learning and retention. Alias emphasizes that microlearning can utilize various technological tools, including videos, podcasts, and gamification, to create engaging and focused learning experiences that cater to diverse learning preferences (Buckley et al., 2018; Moreira et al., 2020; Riska et al., 2021). This aligns with the findings of Sweller, who discusses cognitive load theory, suggesting that breaking down information into smaller chunks can significantly enhance learning outcomes by reducing cognitive overload (Makitan et al., 2024).

Moreover, the incorporation of microlearning within a collaborative framework, such as the Community of Inquiry, further enriches the learning experience. This approach fosters cognitive, social, and teaching presence, which are vital for creating a vibrant learning community. The synergy between microlearning and collaborative learning environments has been shown to enhance student engagement and motivation, leading to better academic performance (Payne, 2024; Spiteri, 2023). Additionally, the active participation encouraged by microlearning strategies not only aids in knowledge retention but also cultivates critical thinking skills, which are essential for students' overall academic development

(Melawati et al., 2022). The advantages of microlearning in enhancing retention and understanding are well-supported by various studies. The method's ability to break down complex information, coupled with active learning strategies and collaborative frameworks, significantly contributes to improved academic performance in mathematics and other disciplines. As educational institutions continue to embrace innovative teaching methods, microlearning stands out as a powerful tool for fostering student engagement and success.

ENGAGEMENT AND MOTIVATION IN THE EXPERIMENTAL GROUP

One of the most significant findings of this study is the high level of engagement and motivation reported by students in the experimental group. Survey results revealed that 85% of students found the microlearning lessons to be engaging and interesting, and 78% reported that the lessons helped them better understand mathematical concepts. These findings support the hypothesis that microlearning can enhance student engagement by offering bite-sized lessons that are both interactive and enjoyable.

The engagement levels observed in the study align with previous research, indicating that microlearning, particularly when enhanced with multimedia and interactive components, significantly boosts student motivation. Mayer's work emphasizes the effectiveness of multimedia in educational settings, suggesting that it can lead to deeper learning and higher engagement levels among students (Fiorella & Mayer, 2018). This is corroborated by Martinho, who notes that microlearning provides a flexible and accessible means for students to review concepts, thereby addressing knowledge gaps and potentially reducing dropout rates (Martinho, 2023). The experimental group in the current study demonstrated a clear preference for microlearning over traditional instructional methods, which they found to be more rigid and less engaging. This preference is indicative of the adaptability that microlearning offers, allowing students to learn at their own pace and revisit materials as necessary, a sentiment echoed in Barus's exploration of microlearning's potential in higher education (Barus, 2023).

Furthermore, the systematic review by Dahalan et al. highlights the importance of instructional design in microlearning, suggesting that well-structured content can significantly enhance student engagement and learning outcomes (Dahalan et al., 2023). The findings indicate that microlearning not only caters to diverse learning preferences but also fosters an environment where students can actively participate in their learning process, thus increasing motivation. This aligns with the principles of the Community of Inquiry framework, which emphasizes the role of cognitive, social, and teaching presence in creating a collaborative learning environment (Kirsch & Mortini, 2023). The interactive nature of microlearning, as discussed by Rizky, further supports its effectiveness in preparing students for assessments like the TOEFL iBT, demonstrating its versatility across different educational contexts (Faizal Rizky et al., 2023). The evidence suggests that microlearning, particularly when integrated with multimedia and interactive elements, significantly enhances student motivation and engagement. The flexibility it offers allows students to tailor their learning experiences, which is increasingly important in contemporary educational settings. The findings from this study resonate with existing literature, reinforcing the notion that microlearning is a valuable pedagogical approach in higher education.

TEACHER OBSERVATIONS AND CLASSROOM DYNAMICS

The observations of higher levels of active participation and engagement among students in the experimental group compared to the control group can be attributed to the characteristics of microlearning, which fosters greater autonomy and independence in students. Research by Martinho emphasizes that microlearning can enhance students' sense of ownership over their learning, as it allows them to engage with short, focused lessons at their own pace (Martinho, 2023). This autonomy is crucial in promoting self-directed learning, which is often linked to increased motivation and sustained engagement (Barus, 2023).

Teachers noted that students utilizing microlearning materials exhibited more enthusiasm and focus, which aligns with findings from Alias, who suggests that microlearning provides learners with the ability to quickly access educational content and tasks, thereby enhancing their engagement and effectiveness in applying learned skills (Huang & Hwang, 2019). The structure of microlearning, which often includes interactive elements and immediate feedback, supports this active engagement, allowing students to take charge of their learning experiences (Lerner et al., 2014).

Moreover, Barus highlights that microlearning not only enables students to consume content but also empowers them to create it, further enhancing their engagement and ownership of the learning process (Barus, 2023). This active participation is essential in cultivating a learning environment where students feel motivated and responsible for their educational outcomes. The findings from this study resonate with the broader literature on microlearning, reinforcing the notion that this pedagogical approach can significantly enhance student engagement and autonomy in various educational contexts (Chen et al., 2023). The higher levels of active participation and engagement observed in the experimental group can be attributed to the autonomy and independence fostered by microlearning. The ability to work on short, focused lessons likely increased students' sense of ownership over their learning, promoting self-directed and sustained engagement.

The observation that control groups exhibited signs of disengagement during traditional lessons aligns with existing literature that critiques conventional teaching methods, particularly for younger students. Teachers have noted that traditional instructional approaches, characterized by extended periods of direct instruction, often lead to decreased motivation and increased distractibility among elementary-aged children. This phenomenon can be attributed to the shorter attention spans typical of this age group, which necessitates more dynamic and engaging teaching strategies to maintain student interest and involvement in the learning process (Alkhateeb, 2014).

Research indicates that integrating innovative educational methods, such as microlearning, can significantly enhance student engagement and learning outcomes. Microlearning, which involves short, focused segments of learning, has been shown to reduce cognitive overload and promote sustained attention, making it particularly suitable for younger learners (Rizky, 2023). For instance, studies have demonstrated that microlearning can help prevent mental fatigue and cognitive impairments, thereby fostering a more conducive learning environment for students who may struggle with longer, traditional lessons (Rizky, 2023). Furthermore, the flexibility of microlearning allows for the reinforcement of concepts in a manner that is both accessible and engaging, which is crucial for maintaining the interest of elementary students (Johnston & Taylor, 2018).

Additionally, the pedagogical design of microlearning emphasizes active participation and interaction, which can counteract the disengagement observed in traditional settings. By incorporating elements of the Community of Inquiry framework, microlearning can enhance cognitive, social, and teaching presence in the classroom, thereby creating a more vibrant and interactive learning community. This approach not only addresses the issue of student disengagement but also aligns with contemporary educational goals that prioritize critical thinking and problem-solving skills among elementary students (Kurniaman et al., 2020). The evidence suggests that traditional teaching methods may not effectively engage elementary-aged children, as reflected in the reported disengagement of control groups during longer lessons. In contrast, microlearning presents a promising alternative that not only caters to the developmental needs of younger learners but also enhances their academic performance and motivation through its innovative and flexible approach to education.

PRACTICAL IMPLICATIONS FOR MATHEMATICS INSTRUCTION

The positive results of this study suggest that microlearning can be a valuable tool in elementary school mathematics classrooms. Microlearning's ability to present content in small, focused units allows for more frequent breaks and provides a manageable learning pace, which can be particularly beneficial for younger students. By breaking down complex mathematical concepts into simpler, more digestible chunks, microlearning helps ensure that students are not overwhelmed by large amounts of information.

Furthermore, the interactive and engaging nature of microlearning lessons appears to be an effective strategy for addressing the common challenges of student disengagement and poor retention in mathematics. The integration of multimedia, quizzes, and interactive activities offers students a more dynamic learning experience, which can help them connect with the material more effectively than traditional lecture-based instruction. For teachers, the results suggest that microlearning-based materials could serve as a supplementary tool to traditional teaching methods. Rather than replacing conventional instruction, microlearning could be used to reinforce key concepts, provide additional practice, and offer differentiated learning experiences. The flexibility of microlearning allows it to be tailored to the specific needs of students, making it easier to accommodate diverse learning styles and abilities within the same classroom.

LIMITATIONS AND CHALLENGES

Despite the positive findings, there were several challenges and limitations in the implementation of microlearning in this study. One of the primary challenges was the technical aspect of delivering the lessons through an online learning management system. While most students were able to navigate the platform with ease, a small number of students initially struggled with accessing the lessons and required additional support. This highlights the importance of ensuring that all students have the necessary digital literacy skills to fully benefit from microlearning-based materials, especially in elementary school settings.

Another limitation was the relatively short duration of the study. Although the results showed significant improvements in academic performance and engagement over the 4 weeks, longer-term studies are needed to determine whether the benefits of microlearning are sustained over time. Additionally, while the study focused on a specific set of mathematical topics, future research could explore the applicability of microlearning across different areas of the mathematics curriculum and in other subjects.

RECOMMENDATIONS FOR FUTURE RESEARCH

Future research should focus on several key areas to explore the effectiveness of microlearning in elementary education further. First, longitudinal studies are needed to assess the long-term effects of microlearning on student learning outcomes. It would be valuable to investigate whether the improvements in academic performance observed in this study are sustained over a longer period and whether microlearning can lead to lasting changes in mathematical skills.

Second, research should examine the scalability of microlearning-based materials in diverse classroom settings. While this study focused on a small sample of students, larger studies across multiple schools and regions could provide more robust insights into the potential of microlearning in elementary education. Furthermore, investigating how microlearning can be integrated into the broader curriculum alongside traditional teaching methods would provide valuable information for educators seeking to implement this approach effectively.

Finally, it would be beneficial to explore the effectiveness of microlearning in different subjects beyond mathematics. Understanding how microlearning can be applied to other areas of elementary education, such as science or language arts, would further contribute to the body of knowledge on the applicability of this approach in diverse educational contexts.

CONCLUSION

This study has demonstrated the effectiveness of microlearning-based materials in enhancing elementary school students' performance, engagement, and satisfaction in mathematics instruction. The key findings indicate that microlearning not only improves academic outcomes but also fosters higher levels of student engagement and motivation compared to traditional teaching methods. The results suggest that by breaking down complex mathematical concepts into smaller, manageable chunks, microlearning can help students process and retain information more effectively.

The findings of this study have important implications for mathematics instruction in elementary schools. Microlearning-based materials offer a viable alternative to traditional teaching methods by providing short, interactive lessons that can be easily integrated into the classroom. These materials can serve as a valuable tool for reinforcing key mathematical concepts, offering personalized learning experiences, and addressing the challenges of student disengagement. For educators, the study suggests that microlearning could be used alongside traditional teaching methods to create a more flexible and engaging learning environment. By incorporating microlearning into their instructional practices, teachers can offer students opportunities to learn at their own pace, receive immediate feedback, and revisit difficult concepts as needed.

Microlearning presents a promising approach to enhancing elementary school mathematics instruction. The positive impact on student performance, engagement, and motivation suggests that microlearning-based materials have the potential to revolutionize the way mathematics is taught in elementary schools. As technology continues to advance, microlearning may play an increasingly central role in shaping the future of education, offering students a more personalized, engaging, and effective learning experience.

REFERENCES

Alias, N. F., & Razak, R. A. (2023). Exploring the pedagogical aspects of microlearning in educational settings: a systematic literature review. *Malaysian Journal of Learning and Instruction*, *20*(2), 267–294. https://doi.org/10.32890/mjli2023.20.2.3

Alias, N., & Siraj, S. (2012). Design and development of physics module based on learning style and appropriate technology by employing the Isman instructional design model. *Turkish Online Journal of Educational Technology*, *11*(4), 84–93. https://doi.org/10.1016/j.sbspro.2013.10.335

Alkhateeb, H. M. (2014). Elementary Education Student Attitudes to Teaching Mathematics: TABLE 1. *Comprehensive Psychology*, *3*, 10.IT.3.6. https://doi.org/10.2466/10.it.3.6

Barus, I. R. G., & Bontisesari. (2023). Exploring the Potentials of Microlearning in English Language Teaching in Higher Education. *Asian Journal of Applied Education (AJAE)*, *2*(4), 557–566. https://doi.org/10.55927/ajae.v2i4.6356

Berger-Estilita, J., & Greif, R. (2020). Using Gagné's "Instructional Design" to teach clinically applicable knowledge in small groups. *Trends in Anaesthesia and Critical Care*, *35*, 11–15. https://doi.org/10.1016/j.tacc.2020.08.002

Buckley, J., DeWille, T., Exton, C., Exton, G., & Murray, L. (2018). A Gamification–Motivation Design Framework for Educational Software Developers. *Journal of Educational Technology Systems*, *47*(1), 101–127. https://doi.org/10.1177/0047239518783153

Chen, J., Fu, Z., Liu, H., & Wang, J. (2023). Effectiveness of Virtual Reality on Learning Engagement: A Meta-Analysis. *International Journal of Web-Based Learning and Teaching Technologies*, *19*(1), 1–14. https://doi.org/10.4018/IJWLTT.334849

Dahalan, F., Alias, N., & Shaharom, M. S. N. (2023). Gamification and Game Based Learning for Vocational Education and Training: A Systematic Literature Review. *Education and Information Technologies*, *29*(2), 1279–1317. https://doi.org/10.1007/s10639-022-11548-w

Dangnga, S. (2020). The Mathematical Instructional Model in Fostering Critical Thinking Article history. *Journal of Research on Mathematical Instruction*, *1*(2). http://jrmi.ejournal.unri.ac.id

Faizal Rizky, M., H, N., & Febriati, F. (2023). Exploring The Potential of Microlearning for TOEFL IBT Preparation Among High School Students. *Journal of Educational Science and Technology (EST)*, *9*(3), 220. https://doi.org/10.26858/est.v9i3.51107

Fiorella, L., & Mayer, R. E. (2018). What works and doesn't work with instructional video? *Computers in Human Behavior*, *Volume 89*, 465–470. https://doi.org/10.1016/j.chb.2018.07.015

Fitriyah, L., Maghfirotun Amin, S., & Yuli Eko Siswono, T. (2020). Designing Open-Ended Instruction for Improving Elementary School Student's Critical Thinking Ability. In *International Journal of Innovative Science and Research Technology* (Vol. 5, Issue 8). www.ijisrt.com

Huang, H., & Hwang, G. J. (2019). Facilitating inpatients' family members to learn: A learning engagement-promoting model to develop interactive e-book systems for patient education. *Educational Technology and Society*, *22*(3), 74–87.

Hutauruk, A. J., Situmorang, A. S., & Sitorus, P. (2021). *Constructing Microlearning Design for Mathematics Learning in School*.

Johnston, K. A., & Taylor, M. (2018). The Handbook of Communication Engagement. In *The Handbook of Communication Engagement*. Wiley Blackwell. https://doi.org/10.1002/9781119167600

Kirsch, C., & Mortini, S. (2023). Engaging in and creatively reproducing translanguaging practices with peers: a longitudinal study with three-year-olds in Luxembourg. *International Journal of Bilingual Education and Bilingualism*, *26*(8), 943–959. https://doi.org/10.1080/13670050.2021.1999387

Kurniaman, O., Noviana, E., & Munjiatun, M. (2020). The ability of critical thinking of elementary school students using a graphic organizer instrument. *JMIE (Journal of Madrasah Ibtidaiyah Education)*, *4*(2), 206. https://doi.org/10.32934/jmie.v4i2.166

Kurnianti, E. M., & Sarifah, I. (2023). The Development of Assessment Instruments of Critical Thinking Ability in Mathematics Learning in Elementary School. *International Journal of Business*, *4*(2), 698–706.

Lerner, R. M., Wang, J., Champine, R. B., Warren, D. J. A., & Erickson, K. (2014). Development of civic engagement: Theoretical and methodological issues1. *International Journal of Developmental Sciences*, *8*(3–4), 69–79. https://doi.org/10.3233/DEV-14130

Makitan, V., Glušac, D., Kavalić , M., & Stanisavljev, S. (2024). The socio-digital engagement of adolescents and their cognitive—Educational needs a case study: Serbia. *Computers and Education Open*, *6*, 100170. https://doi.org/10.1016/j.caeo.2024.100170

Martinho, C., Fernandes, C., & Martins, M. (2023). *The Use of Microlearning as a Complement to Face-to-Face Classes to Reduce Dropout and Improve Academic Success in Higher Education Mathematics* (pp. 54–59). https://doi.org/10.2991/978-94-6463-332-0_7

Melawati, Y., Rochmiyati, R., & Nurhanurawati, N. (2022). A needs analysis of HOTS-based assessment instruments for elementary school mathematics learning. *Asian Journal of Educational Technology*, *1*(2), 90–95. https://doi.org/10.53402/ajet.v1i2.41

Moreira, F., Ferreira, M. J., Escudero, D. F., Salle, L., & Pereira, C. S. (2020). Teaching and learning Modelling and Specification based on gamification. *2020 15th Iberian Conference on Information Systems and Technologies (CISTI), June* 24–27.

Payne, T. (2024). The Math Talk learning environment: Testing an early childhood math intervention. *Early Childhood Research Quarterly*, *66*, 224–233. https://doi.org/https://doi.org/10.1016/j.ecresq.2023.10.012

Riska, N., Handini, M. C., Asmawi, Moch., & in, J. (2021). Instructional-based Gamification in Improving Knowledge in Early Childhood. *International Journal of Early Childhood Special Education*, *13*(2), 948–958. https://doi.org/10.9756/int-jecse/v13i2.211138

Schoenfeld, A. H. (2016). Learning to Think Mathematically: Problem Solving, Metacognition, and Sense Making in Mathematics (Reprint). *Journal of Education*, *196*(2), 1–38. https://doi.org/10.1177/002205741619600202

Mohammed, G. S., Wakil, K., & Nawroly, S. S. (2018). The Effectiveness of Microlearning to Improve Students' Learning Ability. *International Journal of Educational Research Review*, *3*(3), 32–38. www.ijere.com

Spiteri, J. (2023). Intergenerational Learning: Environmental Literacy in the Family and Beyond. *Educating for Sustainability in a Small Island Nation*, *11*, 191–207. https://doi.org/10.1007/978-3-031-23182-7_10

Yin, X., Saad, M. R. B. M., & Halim, H. B. A. (2023). A systematic review of critical thinking instructional pedagogies in EFL writing: What do we know from a decade of research. *Thinking Skills and Creativity*, *49*. https://doi.org/10.1016/j.tsc.2023.101363