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Interactive Digital Comics in Mathematics Learning: A Case Study on Developing Numeracy Literacy in Primary School Student

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ABSTRACT

The research was aimed at applying digital comics presented through interactive panels in mathematics learning to improve the numeracy literacy of elementary school students. A qualitative approach with an intrinsic case study design was conducted at SDN Sertajaya 05 Cikarang. Data were collected through observation, interviews, and documentation, and analyzed using data reduction, data presentation, and conclusion drawing. Findings indicate that digital comics developed through structured storyboards effectively transform abstract mathematical concepts into more concrete, visual, and understandable representations, as visual narratives help students connect mathematical symbols with the learning context. The interactive panel provides a more engaging learning experience by allowing students to navigate, zoom in, and respond to digital quizzes through touch features, which support active participation and instant feedback. Students showed increased motivation, participation, and confidence in completing numeracy tasks. Teachers consider this media effective and appropriate for current pedagogical needs, although challenges remain, particularly in digital literacy and the time required for media development. Interactive digital panel infrastructure plays a crucial role in facilitation. These findings imply that effective integration of digital media in mathematics learning requires adequate technological support and teachers.

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1. INTRODUCTION

Numeracy literacy is one of the fundamental competencies that students need to master from primary school onwards. This ability is not only related to mastery of basic arithmetic operations, but also includes understanding, using, and reflecting on number concepts in everyday life. The Ministry of Education, Culture, Research, and Technology has designated literacy and numeracy as the main focus of the Minimum Competency Assessment (AKM), making the development of learning strategies that support the achievement of these competencies a necessity. Evaluation results such as PISA and various national reports show that students' mastery of literacy and numeracy, especially in developing countries, still needs serious attention, which has led to various innovations in education according to (Widiawati et al., 2025). Limitations in the development of creative and educational learning media are also a significant challenge. According to (Clements et al., 2023), the use of learning media that is appropriate to children's characteristics can increase children's motivation and interest in learning, including in understanding numeracy concepts. However, the reality in the field shows that many teachers are still unfamiliar with designing innovative learning media and utilising simple materials available in their surroundings. It was also found that many students still have difficulty in arithmetic (Hellstrand et al., 2024).

One factor that influences low numeracy literacy achievement is the learning approach, which is still predominantly conventional. Teachers often place more emphasis on mastering procedures and memorising formulas rather than understanding concepts and applying numeracy in real contexts. In fact, primary school children have learning characteristics that favour visual media, narratives, and enjoyable learning experiences. Teachers find it difficult to use online learning media (Agustin et al., 2021). The ability to use technology in the learning process and develop teaching materials is still low (Febrialismanto & Nur, 2020). In this context, innovative learning media play an important role in bridging abstract mathematical concepts to make them easier to understand and meaningful for students (Putri et al., 2022). The impact of e-comic training for primary school teachers is that teachers can create engaging lessons, provide assessments that are appropriate for children, and make students actively participate in learning from home. Mastery of technology based learning media is essential during distance learning to make children's learning experiences more engaging, meaningful, and less tedious (Dewi et al., 2022).

Digital comics are a promising learning medium for supporting the improvement of numeracy literacy. As a combination of text, images, and storylines, comics are able to attract attention, motivate students, and present mathematical material in a context that is closer to everyday life. Several previous studies have demonstrated the effectiveness of comics in mathematics learning. Comic based learning media positively influenced students' understanding of mathematical concepts (Sari et al., 2025). Numeracy based e-comics were feasible to use and received positive responses from primary school students (Mahayani et al., 2024). Digital comics improved the numeracy literacy skills of third grade students (Guntur et al., 2023). Other studies have also indicated that digital comics can enhance learning motivation, creative thinking skills, material comprehension, and vocabulary recognition (Putri et al., 2022; Cahyono et al., 2023; Dewi et al., 2025; Marliana, 2023). In addition, interactive multimedia has been shown to facilitate student engagement and comprehension in elementary mathematics learning (Alyusfitri et al., 2025). However, most existing studies primarily focus on the development stage of digital comic media using research and development designs and quantitative approaches with limited trial implementations. Consequently, these studies provide limited insight into how digital comics are actually

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implemented in real classroom settings, how teachers integrate them into daily instruction, and how students respond during the learning process. Moreover, few studies examine the challenges faced by teachers when using digital comics in technology rich classrooms, such as those equipped with digital interactive whiteboards. Another limitation of previous research is the lack of emphasis on teachers' Technological Pedagogical Content Knowledge (TPACK) in implementing digital comics for numeracy literacy. Although studies have shown that involving prospective teachers in designing digital comics can improve TPACK components, particularly Technological Pedagogical Knowledge and TPACK (Dewi et al., 2025), research that explores the implementation of digital comics from a TPACK perspective in authentic primary school mathematics classrooms remains limited. Therefore, this study seeks to address these gaps by examining the implementation of digital comics in mathematics learning through a qualitative case study, focusing on classroom practices, teacher competence, and student responses in supporting numeracy literacy development.

Based on these conditions, qualitative research is needed to explore in depth how digital comic media is implemented in mathematics learning in primary schools, how students respond to its use, and the obstacles and strategies employed by teachers. This research is expected to provide theoretical contributions in the form of a richer understanding of the integration of digital comic media with numeracy literacy, as well as practical contributions for teachers, prospective teachers, and education policy makers to develop more creative, enjoyable, and contextual mathematics learning.

2. METHODS

This study employed a qualitative approach with an intrinsic case study design to gain an in depth understanding of the implementation of digital comics in improving students' numeracy literacy skills at SDN Sertajaya 05, Cikarang, Bekasi. SDN Sertajaya 05, Cikarang, Bekasi, was selected as the research site because it represents a public elementary school with developing digital learning practices and access to government provided interactive panels that support technology integrated instruction. Preliminary observations indicated that students experienced difficulties in numeracy literacy, particularly in understanding abstract mathematical concepts, highlighting the need for more contextual and visual learning media. In addition, teachers at the school showed openness to implementing digital learning media, despite facing challenges related to digital literacy and instructional preparation time. These conditions made SDN Sertajaya 05 an appropriate and relevant setting for examining the implementation of digital comics in mathematics learning and their potential to improve students' numeracy literacy skills within an authentic classroom context. A qualitative approach was selected because the study sought to explore natural and contextual learning phenomena without manipulating variables, allowing the researcher to interpret participants' experiences and meanings within real classroom settings, as emphasised in qualitative inquiry (Creswell & Creswell, 2022). An intrinsic case study design was adopted because the researcher had a particular interest in a specific case namely, the use of digital comics in mathematics learning at the school with the primary aim not to generalise findings but to obtain a rich, in depth, and holistic understanding of the classroom dynamics.

Data were collected through classroom observations, semi structured interviews, and documentation. Observations were conducted to examine students' learning behaviors, interactions, and engagement during the use of digital comics and interactive panels.

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Interviews involved classroom teachers and selected students to capture their experiences, perceptions, and challenges related to the implementation of the digital comics. Documentation included lesson plans, digital comic materials, students' work, and visual records of classroom activities. Data analysis followed Miles and Huberman's (Ismail et al., 2022) qualitative data analysis model, consisting of data reduction, data display, and conclusion drawing. Data reduction focused on identifying relevant information related to numeracy literacy development and learning engagement. Data display was conducted through thematic organization and narrative descriptions to reveal patterns within the case. Conclusions were drawn iteratively through continuous comparison across data sources. To ensure the trustworthiness of the findings, triangulation of sources, techniques, and time was applied in accordance with qualitative case study methodology.

3. RESULTS AND DISCUSSION

The implementation of digital comics displayed on digital interactive whiteboards at SDN Sertajaya 05 followed a systematic series of preparation, implementation, and reflection, see **Figure 1** and **Figure 2**. In the preparation stage, teachers compiled storyboards and aligned the comic storylines with mathematical learning objectives to improve numeracy skills so that abstract material became contextual and easy to visualise. The use of digital interactive boards allowed teachers to display comic pages interactively because students were involved in using the media by clicking on the screen, touching the screen to turn pages, enlarging illustrations, and marking important elements, so that the media was no longer passive like one way learning videos.

Figure 1. Comic digital mathematics

Mathematics learning using e-comics became a kinesthetic, interactive, and visual learning tool that enabled student participation. According to (Sutriyani et al., 2024), mathematics learning using comics with the webtoon application shows an increase in students' numeracy literacy skills. Recent research shows that digital comics have great potential in improving numeracy literacy and reading skills in primary school students. Digital comics that contain local cultural contexts have been proven to make learning more meaningful and relevant. For example, research by (Bina et al., 2025) found that interactive digital comics based on Karo culture were able to significantly improve students' numeracy skills, with high levels of validity and practicality as assessed by teachers and students.

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Figure 2. Comic digital interactive in class room

These figures demonstrate how the media was applied in real classroom settings, rather than relying solely on textual descriptions. During implementation, classroom observations indicated clear changes in the learning atmosphere. Classes that were previously passive and noisy became more interactive, characterized by active discussions, question and answer sessions, and collaboration among students when solving numeracy problems presented in the digital comics. The interactivity of the digital interactive board enabled students to test their answers directly through digital quizzes, providing immediate feedback. This rapid feedback supported students' understanding and made the mathematics learning process more engaging and effective.

Students' affective and cognitive responses to digital comics combined with digital interactive whiteboards showed an increase in motivation, a decrease in anxiety towards mathematics, and an increase in courage to answer questions in front of the class. Previously, students viewed mathematics as a stressful and boring subject, a pattern commonly found in primary school age (Agustin et al., 2021; Hellstrand et al., 2024). however, after the media intervention, students reported that learning became enjoyable and memorable due to the visual narrative and story context (Dewi et al., 2025). Especially when discussing digital learning media beyond comic, as it shows that technology enhanced learning can improve not only cognition but also affective dimensions like curiosity (Saturohmah et al., 2025). These findings are also supported by evidence that digital comics have been proven effective in improving students' character values during the learning process (Rina et al., 2020).

These results are in line with studies on the influence of interactive whiteboards and touch panels on increasing engagement and the effectiveness of formative assessment in mathematics classes. Ethnomathematics based research also reinforces the effectiveness of digital comics. Developed an ethnomathematics comic about the Al-Akbar Mosque in Surabaya and reported that this medium not only improved students' numeracy skills but also their literacy skills (Pramulia et al., 2025). Furthermore, expanded on this innovation by adding augmented reality technology, which made the comics more interactive and supported the contextual understanding of mathematical concepts(Pramulia et al., 2025).

The active participation of students who are part of Generation Alpha, who are very familiar with technology, appears to be strong. They quickly adapt to digital interactive whiteboards, show a tendency towards independent exploration, and utilise access to digital

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comics to review their learning at home. This phenomenon underlines the importance of designing media that suits the characteristics of today's children so that learning transfer to the home context occurs (Setiyorini & Jayanti, 2025).

From the teachers' perspective, digital comics displayed via digital interactive whiteboards are considered effective in improving students' understanding of numeracy concepts and participation, but they require an investment of time and new competencies. Teachers reported that creating storyboards, visual designs, and digital quizzes requires digital literacy skills that some teachers do not yet fully possess, as previous practices have relied more on non-interactive media such as videos or static images. These findings are consistent with TPACK studies showing that the adoption of interactive media requires a balance of pedagogical and technological skills (Ismail et al., 2022).

Technical constraints such as long development times, training requirements, and occasional device or network disruptions were also identified as barriers to implementation. However, infrastructure support, particularly the availability of government provided digital interactive whiteboards, was a crucial enabling factor that allowed teachers to continue interactive learning despite their limited digital literacy. Other studies have also found that the sustainability of digital innovation depends on continuous training, collaboration between teachers, and managerial support at the school level.

Pedagogically, the mechanism for improving numeracy literacy through digital comics can be understood through four main indicators. First, the contextualisation and concretisation of concepts is carried out through narrative visual representations that help reduce students' cognitive load. Second, motivation and self-efficacy increase because the stories and characters in the comics are designed to be relevant to students' learning experiences. Third, social interaction is built through discussion and collaboration that arises from the learning scenarios embedded in the comic's storyline. Fourth, the opportunity to access the material again at home allows for repeated practice that supports the reinforcement of understanding. Effective mathematics learning in children must follow learning trajectories, namely a series of learning objectives, conceptual developments that children usually go through, and teaching strategies that are in line with these stages (Clements et al., 2023). They emphasise that children understand numeracy concepts better when mathematical ideas are presented through meaningful, engaging, and developmentally appropriate activities, supported by visual or concrete representations that can reduce cognitive load. An interactive learning environment that provides opportunities for exploration and repeated practice is also considered crucial as it helps children build deeper understanding and progress gradually along their learning trajectory.

The empirical findings in this study reinforce these four indicators, as demonstrated by the improvement in the quality of students' answers to numeracy tasks and increased verbal participation during the learning process.

To maximise the impact of these research findings, the researchers recommend several implementation practices, such as the development of collaborative storyboards between teachers for efficiency and effectiveness in creating digital comics, the use of platforms such as Canva Pro in creating e-comics that are user friendly for teachers so as to minimise technical barriers, and digital literacy training programmes focused on creating interactive digital media and teachers' TPACK skills.

Teachers need to receive training in numeracy literacy because the government is currently developing AKM and measuring changes in numeracy literacy skills systematically. Assistance for teachers plays an important role in strengthening their understanding and ability to develop AKM questions based on literacy and numeracy (Hermansyah et al., 2024).

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Digital media facilities and infrastructure are necessary for the regular learning system. Digital media in learning provides many benefits, including increasing students' interest in learning, reducing boredom, and creating a positive learning atmosphere that can strengthen the relationship between teachers and students (Novela et al., 2024).

Overall, the findings at SDN Sertajaya 05 reveal that e-comics combined with digital interactive whiteboards can be an effective innovation in mathematics learning in primary schools, especially among students who are very enthusiastic and motivated to learn mathematics. However, at the implementation stage, teachers still find it difficult to create digital comic media because they are not yet accustomed to using digital interactive boards, so they still need strategies and support in the form of ongoing TPACK training.

4. CONCLUSION

This case study demonstrates that the implementation of digital comics supported by interactive digital boards at SDN Sertajaya 05 has the potential to enhance the quality of mathematics learning by presenting concepts in a more concrete, contextual, and visually accessible manner. The integration of touch based interaction, digital quizzes, and narrative driven content fostered greater student engagement, participation, and motivation, particularly aligning with the learning characteristics of Generation Alpha.

From the teachers' perspective, interactive digital comics were perceived as effective in supporting students' numeracy literacy. However, challenges related to teachers' digital literacy, time constraints in media development, and technical issues remain evident. Despite these limitations, the availability of interactive panel infrastructure played a significant role in facilitating successful classroom implementation. Overall, this study suggests that interactive panel based digital comics can serve as a promising instructional innovation in primary mathematics education, provided that sustained professional development and ongoing mentoring are available to support teachers' pedagogical and technological competencies. Given that this study employed a qualitative case study approach in a single school context, future research is recommended to examine the long term impact of interactive panel based digital comics on students' numeracy literacy through longitudinal designs and multi-site case studies. Further studies involving larger and more diverse school settings are needed to explore the transferability of the findings across different educational contexts. In addition, future research may investigate the integration of digital comics with various mathematical topics and instructional models to provide a more comprehensive understanding of their effectiveness in supporting numeracy learning.

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