Enhancing Mathematics Quality of Instruction (MQI) Competency in Pre-Service Teachers through Digital Flipbooks: Digital Didactics Design

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***Abstract*—This study aims to investigate the impact of using numeracy-based digital flipbooks in enhancing the Mathematics Quality of Instruction (MQI) among students in Mathematics. The background highlights the challenges in improving students' understanding and competency in mathematics. The use of digital technology is identified as a potential solution to improve mathematics learning. The research method involves the implementation of digital flipbooks in the context of mathematics teaching and data collection to measure the improvement in MQI. The research method used is a quasi-experimental design with a non-randomized Pretest-Posttest Control Group. Data collection techniques include practice tests of Mathematics Quality of Instruction (MQI) competence, observations, and interviews. The results of the study show that the significance value of the 2-tailed t-test is 0000 < 005, indicating that numeracy-based digital flipbooks have a significant impact on MQI. Furthermore, the effect size from Cohen's d test shows a score of 495, indicating that numeracy-based digital flipbooks have a very high positive impact on MQI. Other findings show that digital flipbooks make learning more interactive, facilitate evaluation processes, and increase student activity. They also enhance creativity and ICT skills among prospective teachers. Numeracy-based digital flipbooks have a significant impact on the Mathematics Quality of Instruction (MQI) of primary school student teachers in mathematics teaching.**

***Keywords*—digital flipbook, mathematics quality of instruction, numeration, primary school**

I. Introduction

In the evolving context of education, ensuring the quality of instruction is crucial for fostering deep understanding and strong skills in students [1, 2]. The Mathematics Quality of Instruction (MQI) framework serves as a benchmark to evaluate and improve teaching practices, emphasizing clarity in material delivery, teachers' ability to engage and stimulate student creativity, and the use of relevant and interactive teaching methods [3–5]. Improving the quality of mathematics learning for pre-service teachers is crucial to ensure that future educators are equipped with the skills necessary to teach complex concepts effectively. By strengthening their foundational understanding and pedagogical strategies through digital tools, pre-service teachers can foster better student outcomes in mathematics. This research aims to address the pressing need for innovative instructional methods that empower pre-service teachers to excel in an evolving educational landscape. With the advancement of digital technology in the education sector, the integration of innovative tools like digital flipbooks shows great potential for enhancing teaching effectiveness. Digital flipbooks, with their multimedia and interactive capabilities, offer a dynamic platform that can transform traditional mathematics teaching into a more engaging and comprehensive learning experience [6, 7].

Despite their potential, many mathematics classrooms worldwide still rely on conventional teaching methods [8]. These traditional approaches often emphasize rote memorization and mechanical problem-solving, which can hinder students' deep understanding of mathematical concepts and their ability to apply these concepts in real-life situations [9, 10]. The gap between desired curriculum goals, such as fostering flexible problem-solving abilities, and prevalent teaching practices highlights a critical issue in mathematics education [11–13]. The persistent reliance on traditional methods underscores the need for a pedagogical shift towards more interactive and student-centered learning experiences [14].

Existing research highlights the benefits of integrating technology into education. Studies show that digital tools can enhance student engagement, motivation, and learning outcomes [15, 16]. However, there is a lack of literature on the specific impact of digital flipbooks on the quality of mathematics teaching [17]. Although digital flipbooks have been used in various educational contexts, their application in mathematics teaching, especially within the MQI framework, remains underexplored. To address this gap, it is essential to examine existing research on the effectiveness of digital tools in education, particularly in mathematics instruction. While some studies have highlighted the benefits of multimedia learning and interactivity in boosting student engagement and comprehension, few have focused on how digital flipbooks specifically contribute to mathematics education [18]. Additionally, the literature does not yet provide a thorough analysis of how digital flipbooks can be integrated with the Mathematics Quality of Instruction (MQI) framework to enhance instructional clarity, student reasoning, and the depth of mathematical content. These gaps indicate the need for further research that investigates the role of digital flipbooks in improving the quality of mathematics teaching, particularly for pre-service teachers [19]. This gap presents a significant opportunity to investigate how digital flipbooks can be effectively used to enhance teaching quality and student learning outcomes in mathematics.

The primary objective of this study is to examine the effectiveness of digital flipbooks in enhancing the Mathematics Quality of Instruction (MQI) competency among prospective primary school teachers. By integrating digital flipbooks into the mathematics curriculum, this study aims to provide empirical evidence on how these tools can transform teaching practices and improve student learning outcomes. Specifically, the study will assess how digital flipbooks influence various dimensions of MQI, including the clarity of mathematical explanations, the ability to stimulate student engagement and creativity, and the use of interactive and relevant teaching methods [20, 21].

To address the identified gap, this study will employ a mixed-methods approach, combining quantitative and qualitative data to provide a comprehensive understanding of the impact of digital flipbooks. The quantitative component will involve a quasi-experimental design, comparing the mathematics performance of prospective teachers taught using digital flipbooks with those receiving traditional instruction. Key performance indicators will include students' understanding of mathematical concepts, problem-solving abilities, and their engagement with the material. The qualitative component will involve classroom observations and interviews with lecturers and students to gain insights into their experiences and perceptions of using digital flipbooks in mathematics teaching.

The hypothesis underlying this study is that the integration of digital flipbooks into the mathematics curriculum will significantly enhance MQI competency among prospective primary school teachers. It is expected that digital flipbooks will facilitate clearer and more engaging explanations of mathematical concepts, increase student engagement and creativity, and support the implementation of interactive and relevant teaching methods [22]. Additionally, it is hypothesized that prospective teachers taught using digital flipbooks will show improved problem-solving skills and a deeper understanding of mathematical concepts compared to those receiving traditional instruction [23, 24].

Thus, this study aims to bridge the gap in the literature on the use of digital flipbooks in mathematics teaching and provide valuable insights into their potential to enhance teaching and learning quality. By exploring the impact of digital flipbooks within the MQI framework, this study aims to contribute to the ongoing discourse on digital didactic design and offer practical recommendations for educators seeking to integrate technology into their teaching practices. The findings from this study could have significant implications for mathematics education, potentially leading to more effective and engaging teaching strategies that better prepare students for the challenges of the 21st century.

While previous studies have recognized the benefits of integrating digital tools into education, they often lack a focused analysis of specific technologies such as digital flipbooks in mathematics instruction [16]. Many of these studies emphasize general improvements in student engagement and motivation but fall short of addressing how digital flipbooks can directly impact mathematical understanding and pedagogical quality within structured frameworks like MQI [17, 19]. Furthermore, few studies offer a robust analysis of the limitations of these tools, such as the potential for over-reliance on multimedia features at the expense of deep mathematical reasoning [20, 21]. Given these strengths and weaknesses, this research is necessary to fill the void in understanding the nuanced role digital flipbooks can play in enhancing mathematics teaching. The rationale for this study is rooted in the growing demand for evidence-based practices that integrate technology into the classroom, as well as the need to provide pre-service teachers with effective methods to improve their instructional quality [22]. Drawing from the gaps in the literature, this research aims to build on the strengths of prior work while addressing their limitations, providing a more comprehensive perspective on the use of digital flipbooks in mathematics education.

II. Literature Review

A. Mathematics Quality of Instruction (MQI)

The Mathematics Quality of Instruction (MQI) is based on the perspective that mathematical activities occurring in the classroom differ from the classroom climate, pedagogical style, or the implementation of general learning strategies [25, 26]. In MQI, teachers are given separate assessments for various aspects of mathematical work performed; for example, the ability to provide explanations and mathematical practices are assessed separately from student participation in the process [27]. This makes MQI a unique instrument among various mathematical teaching assessment tools, many of which prioritize new practices over considering in balance the various elements that make up mathematics learning.

The quality of teaching materials and resources significantly influences mathematics learning outcomes. Well-designed textbooks, digital resources, and teaching aids enhance student self-practice and skill reinforcement [15, 28, 29]. Continuous professional development for teachers is crucial for improving MQI. Training programs that focus on enhancing teacher content knowledge, pedagogical techniques, and assessment strategies empower them to deliver high-quality instruction and effectively address the diverse needs of students [30].

To measure teaching quality, [31] designed the Mathematical Quality of Instruction (MQI) instrument. This instrument reflects the interaction between teacher, student, and content during mathematics instruction [32]. The MKT model forms the basis for the MQI instrument, where the interaction between teacher and MKT (content) relates to subject matter knowledge and teacher-student interaction relates to pedagogical content knowledge (Fig. 1).

In the interaction between teacher and content, the dimension of mathematical depth captures the level of mathematical depth offered to students. There are two categories within this dimension: the focus on the meaning of facts and procedures, and the focus on the practice of mathematical problem-solving. The dimension of errors and inaccuracies pertains to mistakes and inaccuracies in language and notation, or a lack of clarity/rigor in the presentation of the content by the teacher. Working with students and mathematics captures whether the teacher can understand and respond to students' mathematical contributions or mistakes [4, 5].

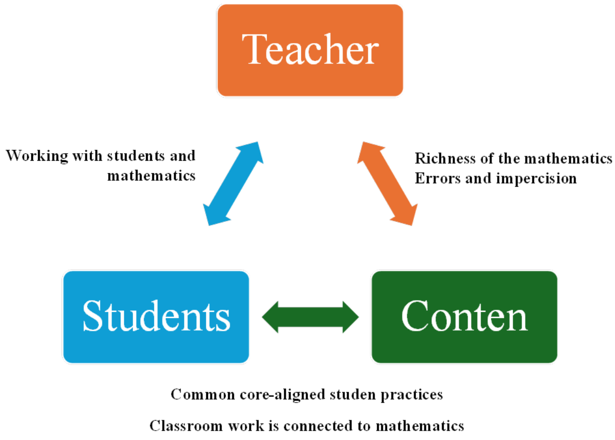

Fig. 1. Instructional dimensions measured by MQI (National Center for Teacher Effectiveness, 2009).

The selection of teaching media is an important aspect that teachers must consider in the teaching process. The appropriate choice of learning media can attract students' attention and facilitate the understanding of the material [33, 34]. Therefore, innovation in teaching approaches, especially in the use of various learning media, is necessary. To support the use of such learning media, further development is needed. This aims to clarify the delivery of the material and relate it to everyday life contexts, thus making it easier to understand abstract concepts and connect them to real-life situations [35]. One example of learning media that teachers can utilize is the flipbook.

B. Digital Flipbook

A flipbook is a type of learning media like a book, featuring a virtual album-like display that contains learning material presented in colorful sentences [6, 20]. The design of the flipbook is made as attractive as possible by using a combination of colors that catch students' attention, making them more active and enthusiastic in the learning process [21]. The flipbook is equipped with text, images, animations, videos, and sound, making it an engaging learning medium that supports the learning process [22, 23]. With advances in Information and Communication Technology (ICT), flipbooks can now be presented digitally with navigation features that make user interaction more dynamic. In this study, conventional flipbooks, which are in paper form, are transformed into digital flipbooks. These digital flipbooks present learning material structured in the smallest learning units, aiming to achieve specific learning objectives [24].

A digital flipbook is a learning medium like a book but in digital form. Each page in the book can be flipped, and it includes colorful images and sound elements that can attract students' interest. Digital flipbooks can be utilized in all subjects. Hashrin & Lestyanto [36] and Ristanto *et al.* [37] state that flipbooks have several advantages, including their ability to present learning material in the form of text, sentences, and images. These images are often color-coded to attract students' interest. Additionally, flipbooks are relatively easy to create, portable, and can increase student learning activity. Flipbooks also help students handle abstract material or events that are difficult to understand in class [38]. Digital flipbooks use audiovisual displays such as text, audio, video, graphics, and animations. The use of flipbook software is expected to be easily understood and to become an effective learning medium.

Digital flipbooks can be integrated into all subjects and topics, including numeracy. Numeracy-based digital flipbooks serve as learning tools that can enhance students' understanding and numeracy skills [39, 40]. These numeracy-based flipbooks are designed to help students comprehend mathematical concepts and develop counting skills interactively. An important aspect of numeracy-based digital flipbooks is their ability to present mathematical concepts visually and dynamically [41]. By using animations and graphics, flipbooks can illustrate mathematical and numeracy processes more clearly and capture students' attention [42]. For instance, flipbooks can be used to visualize mathematical operations such as addition, subtraction, multiplication, and division in ways that are easy for students to understand. Numeracy-based digital flipbooks can also enhance students' counting skills through interactive exercises. By presenting learning material in an engaging and interactive format, flipbooks can help students feel more involved in learning mathematics and more motivated to learn. Research indicates that when students interact with multimedia elements such as animations, simulations, and interactive exercises, they often experience improved understanding and retention of complex mathematical concepts. Specifically, studies have shown that digital flipbooks can facilitate a deeper comprehension of mathematical processes by allowing students to visualize and manipulate mathematical concepts dynamically. Moreover, the interactive nature of flipbooks supports differentiated learning, enabling students to progress at their own pace and revisit challenging topics as needed. The main findings of recent research on digital flipbooks suggest that they can enhance student engagement and motivation, improve conceptual understanding, and provide valuable feedback for both students and teachers. However, further investigation is needed to assess how effectively these tools integrate with established instructional frameworks, such as the Mathematics Quality of Instruction (MQI), to maximize their educational impact [23, 36, 39].

III. Materials and Methods

A. Research Design

This study aims to determine the effect of a numeracy-based digital flipbook on the Mathematics Quality of Instruction (MQI) among students in Elementary School Teacher Education. The type of research used is quantitative research with a quasi-experimental method. This is because the subjects receiving the treatment cannot be fully controlled. Experimental research is designed to test the impact of a treatment on research outcomes, which are controlled by other factors that also influence those outcomes [43].

The research design used in this study is the non-randomized Pretest-Posttest Control Group Design. There are control and experimental classes where, in practice, the experimental class is given treatment in the form of numeracy-based digital flipbook learning activities, while the control class undergoes regular learning activities without using the digital flipbook. Through this process, the effect of the numeracy-based digital flipbook on improving the Mathematics Quality of Instruction (MQI) among Elementary School Teacher Education students can be determined. The research design is illustrated in the following Table 1.

Table 1. Research design

Group	Pre-test	Intervention	Post-test
Control	O_1	X_c	O_2
Experiment	O_3	X_r	O_4

Source: Johnson & Christensen (2014).
Code Information:
O_1: *Pre-test* control group
O_2: *Post-test* control group
O_3: *Pre-test* experiment group
O_4: *Post-test* experiment group
X_c: The treatment uses printed book learning
X_r: The treatment uses numeracy-based digital flipbook learning

B. Sample and Population

This study was conducted with students from the Elementary School Teacher Education program at Yogyakarta State University. This is because these students are prospective teachers who will teach at the elementary level and need to master various subject competencies, including mathematics. The population in this study comprises all students in the Elementary School Teacher Education program at Yogyakarta State University. The sampling technique used in this study is purposive sampling. Purposive sampling is a data collection technique based on selecting certain characteristics or traits to obtain a relevant sample for achieving the research objectives [44]. In this research context, the sample was chosen by considering the courses taken by the Elementary School Teacher Education students. Therefore, this study was conducted on students who are currently or have already taken elementary-level mathematics teaching courses.

C. Measurement and Data Collection

The data for this study were collected from students, lecturers, and documents during the implementation of the teaching process and learning activities. Data collection techniques included interviews, observations, and practical tests. This study employed several instruments to gather valid data: interview guides, observation guides, and pre- and post-treatment MQI practical tests for students in the Elementary School Teacher Education program. The interview guides were designed to collect in-depth qualitative data regarding the experiences and perceptions of students and lecturers about the use of the numeracy-based digital flipbook. The guides included structured and semi-structured questions to ensure comprehensive coverage of the topics [32]. The reliability of the interview guides was established through a pilot test with a small group of participants, and adjustments were made based on their feedback to enhance clarity and comprehensiveness [15]. The observation guides were used to systematically observe and record the teaching and learning activities in the classroom. These guides included specific indicators of teaching quality and student engagement, aligned with the MQI framework [23]. The reliability of the observation guides was ensured through inter-rater reliability checks, where multiple observers independently scored the same sessions, and their scores were compared to ensure consistency [32]. The MQI practical tests were administered to students before and after the treatment to measure changes in their mathematics teaching quality.

The tests included items that assessed various dimensions of MQI, such as mathematical depth, error identification, and responsiveness to student contributions. The reliability of the MQI practical tests was confirmed through a test-retest method, where the same test was administered to a subset of students at two different points in time, and the scores were compared to check for consistency [43]. By using these validated and reliable instruments, the study aimed to ensure the accuracy and validity of the collected data, providing robust evidence for the impact of the numeracy-based digital flipbook on the Mathematics Quality of Instruction (MQI) among students in the Elementary School Teacher Education program.

All the instrument is already test by Confirmatory Factor Analysis to ensure the validity and reliability of instrument. To assess the construct validity of the measurement instrument, the researcher refers to two aspects, namely convergent validity and discriminant validity. Convergent validity is assessed based on the value of Average Variance Extracted (AVE) with a minimum threshold of $\alpha \geq 0.50$. Meanwhile, for discriminant validity, the researcher examines the Heterotrait-Monotrait Ratio (HTMT) with a minimum threshold of $\alpha \leq 0.85$. For instrument reliability, the reference used is Composite Reliability (CR), with a minimum acceptable value of $\alpha \geq 0.70$. The results of the CFA analysis indicate the AVE, HTMT, and CR values for the three measurement instruments. All three instruments have AVE values of $\alpha \geq 0.50$ (interview with 0.51, observation with 0.68, and MQI test with 0.062), indicating that more than 50% of the indicators can be explained by their latent constructs. For the HTMT values, all three variables also meet the criterion of $\alpha \leq 0.85$ (interview with 0.65, observation with 0.57, and MQI test with 0.62), meaning that each item does not correlate or interfere with the latent variables. Since both aspects are met, the measurement instruments used can be considered valid. In terms of instrument reliability, the CR values of the three instruments also meet the threshold of $\alpha \geq 0.70$ (interview with 0.78, observation with 0.84, and MQI test with 0.72), indicating that all three variables are reliable. Thus, the three variables are valid and reliable for measuring the research data.

D. Data Analysis

The data were analyzed quantitatively, both descriptively and inferentially. Descriptive statistics were used to present the data obtained from the pretest and posttest results of this study. Initial condition data are useful for providing an initial overview of the subjects in both groups. The final condition data were obtained to describe the impact of the numeracy-based digital flipbook on the improvement of Mathematics Quality of Instruction (MQI) competencies among Elementary School Teacher Education students, presented in the form of averages, standard deviations, minimum, and maximum values.

Before conducting statistical tests, classical assumption tests, including normality and homogeneity tests, were performed. The purpose of the normality test is to determine whether the data distribution is normal. The data distribution is considered normal if the significance value is greater than 0.05 (Sig > 0.05). The homogeneity test aims to determine the equality of variances across the population data. The data are considered homogeneous if the significance value is greater than 0.05 (Sig > 0.05).

After conducting the classical assumption tests, statistical tests or hypothesis testing were performed. The hypothesis of this study:

H0: There is no effect of the numeracy-based digital flipbook on the improvement of Mathematics Quality of Instruction (MQI) competencies among Elementary School Teacher Education students.

Ha: There is an effect of the numeracy-based digital flipbook on the improvement of Mathematics Quality of Instruction (MQI) competencies among Elementary School Teacher Education students.

Hypothesis testing is conducted using parametric statistical tests (t-test) when the data are normally distributed and homogenous. Conversely, nonparametric statistical tests are employed when these assumptions are not met. Through hypothesis testing, conclusions can be drawn regarding the impact of numeracy-based digital flipbooks on the improvement of Mathematics Quality of Instruction (MQI) competence among elementary education students. Following hypothesis testing, an effect size analysis is performed to determine the magnitude of the influence of numeracy-based digital flipbooks on the enhancement of Mathematics Quality of Instruction (MQI) among elementary education students.

IV. Result and Discussion

A. Result

This research aims to measure Mathematics Quality of Instruction (MQI) using numeracy-based digital flipbooks implemented by 50 elementary education students at Universitas Negeri Yogyakarta during classroom teaching with primary school students. Students utilized numeracy-based digital flipbooks in teaching mathematics. MQI measurement is based on five indicators developed by Harvard University: mathematical learning activities, student engagement, teacher response, teaching strategies and methods, and accuracy and misconceptions across 20 statement items. Initial findings indicate low MQI among students, with 70% not yet reaching the "good" category. This is evidenced by weak teacher-student interactions during teaching, underutilization of teaching media, and teachers' unpreparedness for incidental situations during teaching processes.

Numeracy-based digital flipbooks were implemented to enhance MQI among elementary education students. Students were guided to create, develop, and implement numeracy-based digital flipbooks over 6 sessions. They were also equipped with knowledge of planning, implementation, and evaluation of teaching integrating numeracy-based digital flipbooks into mathematics instruction. These elementary education students then became teaching interns who implemented numeracy-based digital flipbooks according to the curriculum in classrooms where they practiced teaching. Results from teaching processes after using numeracy-based digital flipbooks show a 96% improvement, with most students reaching at least the "good" category or above. This is supported by more interactive mathematics teaching between interns (student teachers) and students. Teachers responded positively to stimuli provided by students, and students were able to express opinions and questions effectively to teachers. Additionally, the use of numeracy-based digital flipbooks encouraged active learning and generated high motivation among students.

After implementing numeracy-based digital flipbooks in teaching mathematics, elementary education students reported that the use of these media positively supported the learning process. Students became more active and responsive during learning because they were interested in the media. Furthermore, students were trained to use ICT wisely. Importantly, students could develop their creativity in designing and creating numeracy-based digital flipbooks. In the design and creation process, students aimed to match the material with student characteristics and anticipate unforeseen disruptions during teaching. Moreover, students' ICT mastery skills improved; initially, they struggled to develop the media but eventually utilized it effectively in teaching. Based on these descriptions, the implementation of numeracy-based digital flipbooks indirectly enhances students' creativity and ICT mastery skills, both crucial in realizing 21st-century learning.

The use of numeracy-based digital flipbooks ultimately impacts MQI among elementary education students. Based on the research findings, scores before and after using numeracy-based digital flipbooks can be detailed in Table 2.

Table 2. Pretest and Posttest MQI Score

Group	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum	Mean of N-Gain Score
Pretest	50	46.12	7.615	1.077	31	65	0.48 (Moderate)
Posttest	50	61.60	6.779	0.959	45	77	

Source: SPSS Data

Based on Table 2, there was an increase in students' MQI scores from an average of 46.12 before using digital flipbooks to 61.60 after using them, marking an increase of 15.48 points. This difference in means yields an N-Gain score of 0.48, categorized as moderate. Thus, the use of numeracy-based digital flipbooks has a positive impact on enhancing MQI among elementary education students. However, this improvement needs further testing to ascertain its significance and the extent of its influence through hypothesis testing. Prior to hypothesis testing, prerequisites such as normality and homogeneity tests were conducted using SPSS 16.0 software. The results of normality and homogeneity tests from the obtained data can be detailed in Table 3.

Table 3. Results of normality test and homogeneity test of MQI data

Kelas	Kolmogorov-Smirnov[a]			Homogeneity of Variances			
	Statistic	df	Sig.	Levene Statistic	df1	df2	Sig.
Pretest	0.086	50	0.200*	0.292	1	98	0.590
Posttest	0.098	50	0.200*				

*: This is a lower bound of the true significance.
a: Lilliefors Significance Correction
Source: SPSS Data

Based on the above output, it shows that the significance value (*p*-value) of the students' MQI scores in the Kolmogorov-Smirnov test is 0.200 > 0.05. Referring to the significance level of 5%, this value (> 0.05) indicates that all MQI data, both pretest and posttest, follow a normal distribution. From this, we can conclude that the data obtained from both the pretest and posttest phases are normally distributed. Additionally, based on the Test of Homogeneity of Variances table, the significance value is 0.590 > 0.05. This score indicates that the data are homogenous. Therefore, since the data meet the criteria of normality and homogeneity, we can proceed with hypothesis testing using parametric statistics, specifically paired t-tests. The results of the paired t-test can be detailed in Table 4.

Table 4. Paired T test results

Paired Differences					t	df	Sig. (2-tailed)
Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
			Lower	Upper			
−15.480	3.125	0.442	−16.368	−14.592	−35.029	49	0.000

Source: SPSS Data

The paired sample t-test was carried out to determine whether there was a significant difference in the average MQI score before and after treatment using a numeracy-based digital flipbook for students. Determining the hypothesis depends on the comparison of the magnitude of the significance value (Sig.) obtained. If the significance value (Sig.) obtained is > 0.05 then H0 is accepted, and Ha is rejected. However, if the significance value (Sig.) obtained is <0.05 then H0 is rejected, and Ha is accepted. Based on the output of the paired sample t-test, the overall Sig (2-tailed) value of the data is 0.000 < 0.05. These results show that H0 is rejected, and Ha is accepted. Therefore, there is a significant difference in the average MQI scores of students before and after using numeracy-based digital flipbooks so that there is a significant influence. Next, the Cohen-d test was carried out to find out how much influence (effect size) the numeracy-based digital flipbook had on increasing students' MQI. The results of the Cohen-D effect size test can be described in Table 5.

Table 5. Effect size test results

Data	α	St.dev	Cohen-d
Pretest dan Posttest	15.48	3.125	4.95

Source: SPSS Data

The effect size test is conducted by dividing the mean difference between pretest and posttest scores (α) by the standard deviation of the data. Based on the effect size test results, a Cohen's d score of 4.95 is obtained, indicating a value above 1.30, categorized as very high. Based on these results, the use of numeracy-based digital flipbooks has a statistically significant and very high impact on MQI among elementary education students.

B. Discussion

Development of numeracy-based digital flipbooks integrates numeracy learning in a more engaging manner for students [6]. Numeracy is a fundamental aspect of elementary mathematics education that often requires strategies to help students derive meaning and benefit from the learning process. In this study, numeracy-based digital flipbooks strive to integrate numeracy learning with evolving technological advancements of the current era. This effort aims to yield positive impacts for both teachers and students.

The use of numeracy-based digital flipbooks in education has shown positive effects on the quality of mathematics instruction. Digital flipbooks enable interactive simulation through electronic formats that incorporate animations, text, videos, images, audio, and engaging [20], aligning with the media implemented in this research. These flipbooks aim to facilitate students' full potential by combining engaging elements such as images, animations, text, videos, and navigation. Consequently, the presentation of numeracy-based digital flipbooks simplifies students' comprehension of materials presented by teachers and supports the learning process [21]. The possible reasons behind this result can be attributed to several factors. First, the multimedia content in digital flipbooks caters to various learning styles visual, auditory, and kinesthetic allowing students to engage with mathematical concepts in multiple ways. This multimodal approach enhances cognitive processing and helps students form stronger connections between abstract concepts and real-world applications. Second, the interactivity of digital flipbooks allows for a more personalized learning experience, enabling students to control the pace of their learning, revisit complex topics, and receive immediate feedback. This autonomy fosters a more active learning environment and improves student engagement. Lastly, the visual and animated features of flipbooks help to break down complex mathematical ideas into more digestible parts, reducing cognitive overload and making abstract concepts more concrete and understandable. These factors collectively contribute to the effectiveness of numeracy-based digital flipbooks in improving mathematics instruction [23].

The teaching practice conducted by elementary education students (as teaching interns) becomes more interactive when using digital flipbooks. Students exhibit increased confidence in teaching processes, readiness to handle incidental events, and improved classroom management skills. Students are more focused and enthusiastic during learning processes. The interactive methods facilitated by digital flipbooks enhance student engagement, making learning more enjoyable and capturing students' attention [24, 45]. The possible reasons behind this result can be attributed to several key factors. First, the visually appealing and interactive nature of digital flipbooks engages students more effectively by incorporating multimedia elements such as videos, animations, and simulations, which capture their attention and sustain focus during the lesson. This enhanced engagement reduces distractions and supports better classroom management. Second, digital flipbooks offer pre-structured content that helps teaching interns plan their lessons more efficiently, leading to greater confidence and preparedness when handling classroom activities or unexpected situations [36]. This level of preparation allows interns to respond quickly and calmly to incidental events, further improving their classroom management skills. Additionally, the interactive features of the digital flipbooks encourage active participation from students, making the learning experience more dynamic and hands-on. This active involvement keeps students motivated and interested in the lesson, contributing to an overall positive learning environment. Ultimately, these factors combine to improve both the instructional quality and classroom dynamics when digital flipbooks are utilized. Positive interactivity in education contributes to overall instructional quality. Furthermore, the use of digital flipbooks aids teachers in effective classroom management [37].

Flipbooks presented electronically integrate interactive simulations with animations, text, videos, images, audio, and navigation. Flipbooks not only make reading more enjoyable for students but also offer several benefits. Learning materials are presented through enriched visuals, words, and sentences enhanced with color to attract attention. Digital flipbooks are cost-effective, easy to create, portable, and encourage student participation [38, 46]. They also help students understand complex or abstract concepts that are difficult to grasp through traditional methods. Key advantages of implemented numeracy-based digital flipbooks include interactive visualization that facilitates enjoyable learning, accessibility via computers, tablets, or smartphones anytime and anywhere, flexibility for students to learn at their own pace and time, and support for continuous learning beyond the classroom [47–49].

The use of digital flipbooks in education not only enhances teachers' creativity but also positively impacts their ICT (Information and Communication Technology) proficiency. Digital flipbooks provide a platform that necessitates comprehensive understanding and application of digital technology, from creation to presentation. Consistent with research by Erna et al., which states that the use of digital flipbooks encourages teachers to master various software and digital applications, thereby enhancing their technological proficiency [50, 51]. Moreover, integrating technology in teaching, as supported by this study, aligns with previous research that highlights the positive impact of multimedia and digital tools on student engagement and learning outcomes. Like earlier studies, this research confirms that the use of interactive elements, such as animations, videos, and online resources, enhances the learning experience by making it more engaging and accessible. However, unlike many prior studies that focused broadly on technology integration in education, this study specifically emphasizes the use of digital flipbooks within the Mathematics Quality of Instruction (MQI) framework, providing a more targeted approach to improving mathematical instruction for pre-service teachers. While previous studies have often explored general benefits of digital tools, this research delves deeper into the specific impacts on classroom management, teacher confidence, and student engagement within a mathematics teaching context, thus offering new insights and practical recommendations for educators [52–54]. Thus, digital flipbooks not only enrich teaching methods but also enhance teachers' overall ICT competencies.

V. Conclusion

Based on the findings of the conducted research, numeracy-based digital flipbooks have a significant impact on Mathematics Quality of Instruction (MQI) among elementary education students during mathematics teaching. This is evidenced by the 2-tailed significance value from the paired t-test resulting in a score of $0.000 < 0.05$, indicating that numeracy-based digital flipbooks have a significant effect on MQI. Furthermore, the Cohen's d effect size test yielded a score of 4.95, indicating that numeracy-based digital flipbooks have a very high positive impact on MQI. Another finding from this study is that with the presence of digital flipbooks, elementary education students (prospective teachers) can develop creativity and ICT skills to support 21st-century learning. Additionally, implemented numeracy-based digital flipbooks have positive effects on students, including increased learning motivation, simplified evaluation processes, and enhanced interactive learning experiences. These impacts, beneficial for both teachers and students, closely relate to the improvement of MQI.

This study produced a key finding that numeracy-based digital flipbooks significantly influence the improvement of MQI among elementary education students. This encourages future teachers to continually create effective learning environments from planning to implementation and evaluation to enhance the quality of mathematics instruction. The research indirectly suggests that the use of digital flipbooks can positively impact teachers' creativity and ICT mastery skills. Therefore, it is recommended for future research to provide more detailed explanations through comprehensive studies on the influence of digital flipbooks and other digital media on these aspects. Furthermore, additional research is needed to explore the perceptions of both teachers and students in primary schools regarding the use of digital flipbooks, especially in mathematics education. Moreover, further research and development of similar learning media innovations should adapt to the characteristics and backgrounds of learners to optimize their educational impact.

One limitation of this study is that it primarily focused on elementary education students from a single institution, which may limit the generalizability of the findings to a broader population. Additionally, while the study demonstrated the positive impact of digital flipbooks on MQI, it did not compare the effectiveness of digital flipbooks with other digital teaching methods, leaving room for further exploration. Lastly, the study did not deeply examine the long-term retention of skills and knowledge gained through the use of digital flipbooks, warranting future research to address this aspect.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

F.M & L.Y: Literature review, conceptualization, L.D & A.A.: methodology, data analysis. M.A.M & S.W.: review-editing and writing, original manuscript preparation. All authors have read and approved the published on the final version of the article.

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