Enhancing Metacognitive Processes in Elementary Schools through Technology-Infused Reading Instruction

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Abstract

The objective of this quantitative study is to investigate if the utilization of technology in reading classes enhances the metacognitive processes of primary school students, among other factors. This research investigated the metacognitive awareness, strategic reading practices, and reading comprehension abilities of students. The study involved a six-month intervention period and included pre-and post-test assessments. The experimental group, which was exposed to technology-integrated teaching, and the control group, which received conventional instruction, were randomly assigned 120 students each from two primary schools. This selection employed a deliberate sampling strategy. The data analysis involved the use of descriptive statistics, ANCOVA, Pearson correlation coefficients, and independent samples t-tests. The experimental group exhibited considerably greater levels of metacognitive awareness and reading comprehension compared to the control group. The importance of metacognitive processes in facilitating effective reading comprehension was further emphasized by the significant positive correlation seen between metacognitive awareness and reading comprehension. The study contributes to existing knowledge on the potential benefits of technology-infused education in developing metacognitive skills among primary school children by addressing research gaps and providing empirical evidence.

Keywords: technology-infused instruction, metacognitive processes, elementary education, reading comprehension

Introduction

Within the field of education, the development of metacognitive processes plays a crucial role in promoting academic achievement, especially in the area of reading comprehension. Metacognition, which refers to the conscious understanding and control of one's mental processes, is crucial in helping students develop the ability to independently monitor, assess, and adapt their learning methods (Levin, 1979). The importance of metacognition in reading comprehension is extremely significant since it involves a range of cognitive processes including goal-setting, comprehension monitoring, difficulty identification, and the use of methods to overcome reading hurdles (Savage, 2006). As a result, educators are always looking for new ways to improve the development of metacognition in primary school pupils, to give them the abilities they need to become skilled readers.

Technology has become more valuable in educational contexts, providing distinct possibilities to enhance traditional teaching methods and include students in interactive learning experiences (Jackman, 2018). The use of technology in reading teaching offers opportunities for individualized learning, instant feedback, and immersive learning settings, which can improve metacognitive processes (Draeger & Winckelmann, 2020). Using digital platforms, instructional software, and multimedia resources provides students with many ways to interact with texts, think about their reading methods, and enhance their metacognitive awareness (Yawiloeng, 2022).

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Although there is increasing interest in incorporating technology into teaching, there is still a lack of information regarding its precise influence on metacognitive development, especially in the setting of primary education. Although much research has examined the efficacy of technology in improving academic results, few have specifically examined its impact on metacognitive processes, particularly in the area of reading comprehension. Therefore, it is necessary to conduct a thorough empirical study to investigate the capacity of technology-integrated reading education to promote metacognitive abilities in primary pupils.

This study aims to fill this void by examining the efficacy of technology-integrated reading teaching in improving metacognitive processes in primary schools. This study seeks to utilize a quantitative research methodology to gather empirical information on the effectiveness of technology-infused education compared to traditional reading instruction in enhancing metacognitive development among primary pupils.

The main aim of this research is to investigate if incorporating technology into reading education results in more significant enhancements in metacognitive processes compared to conventional reading instruction. This study will use a well-planned and controlled experiment to investigate how the incorporation of technology affects students' knowledge of their thinking processes (metacognitive awareness), their use of effective reading strategies (strategic reading behaviours), and their general ability to understand what they read (reading comprehension abilities).

To accomplish this goal, the study will utilize theoretical frameworks such as Cognitive Load Theory (Sweller, 1994) and Social Cognitive Theory (Bandura, 1989) to clarify the fundamental mechanisms by which technology might impact metacognitive processes. The theory of Cognitive Load proposes that instructional materials should be created in a way that maximizes cognitive load, allowing learners to effectively absorb information without becoming overwhelmed (Leahy & Sweller, 2015). Through the utilization of technology, educators may provide adaptable and interactive learning experiences, which in turn support students' cognitive processes and promote metacognitive reflection (Visser & Flynn, 2018). Furthermore, the Social Cognitive Theory highlights the significance of observational learning, self-efficacy, and self-regulation in influencing individuals' behaviour (Bandura, 1989). By incorporating technology into their teaching, educators provide students with the chance to witness demonstrated techniques, obtain evaluations on their progress, and progressively cultivate self-assurance in their capacity to manage their learning (Ramirez, 2021).

Problem of the Study

Elementary school instructors in modern educational settings continually encounter the task of cultivating metacognitive processes in their pupils to improve reading comprehension. Although metacognition is widely acknowledged as crucial for academic success, some primary pupils face difficulties in cultivating strong metacognitive abilities. This might hinder their capacity to grasp and successfully connect with texts. Conventional teaching approaches frequently fail to effectively meet the varied requirements of pupils and encourage thoughtful self-awareness during reading exercises. Furthermore, the swift incorporation of technology into educational settings has prompted inquiries regarding its capacity to enhance metacognitive growth. The objective of this study is to examine how technology-integrated reading teaching might improve metacognitive processes in primary school children.

Research Questions

1. Does technology-infused reading instruction lead to greater improvements in metacognitive processes compared to traditional reading instruction among elementary school students?

2. How do students' metacognitive awareness, strategic reading behaviours, and reading comprehension abilities differ between those receiving technology-infused instruction and those receiving traditional instruction?

3. What are the underlying mechanisms through which technology integration influences metacognitive development in the context of elementary school reading instruction?

Significance of the Study

This study offers significant insights into the potential enhancement of metacognitive processes in primary children through the integration of technology in education. These findings have noteworthy consequences for policy and practice. The objective of this research is to provide instructors with novel strategies for fostering metacognitive development in the classroom through a comparative analysis of the efficacy of technology-integrated reading courses. Furthermore, this study's findings might contribute to the ongoing discourse on technology integration in education by providing empirical evidence that supports decision-making at the institutional and governmental levels. The primary objective of this study is to equip instructors with resources that can assist in the cultivation of their students' metacognitive skills. This will ensure that future generations of readers are adequately equipped to navigate the complexities of the digital era.

Limitations of the Study

Although this study seeks to provide vital insights into the effectiveness of technology-integrated reading education, it is important to recognize numerous limitations. Firstly, the extent to which the findings may be applied to other situations may be restricted by the particular circumstances and features of the sample in the research. Furthermore, the length of the intervention period may not adequately measure the long-term impact on metacognitive development, therefore requiring additional longitudinal study. Furthermore, the dependence on quantitative measures may fail to include subtle features of metacognitive processes that qualitative techniques may clarify. Ultimately, the study's results may be affected by external factors such as variations in teaching methods and the dynamics of the classroom. Therefore, it is crucial to interpret the findings cautiously, taking into account the wider educational environment.

Literature review and Previous studies

Understanding and managing our cognitive processes is essential for successful learning and academic success (Reid & Davidson, 2022). In the realm of reading comprehension, metacognitive processes involve a range of cognitive activities. These activities include setting goals, keeping track of understanding, recognizing challenges, and using strategies to overcome obstacles that arise during reading (Channa et al., 2018). Studies indicate that skilled readers possess a deep understanding of their thinking processes, allowing them to employ effective reading strategies and adjust their methods to suit various texts and assignments (Smith & O'Brien, 2016).

In the realm of metacognitive development in elementary students, instructional methods have traditionally centred around explicit teaching strategies. These strategies include think-aloud, reciprocal teaching, and graphic organizers, as highlighted by Noviani, (2021) and Motsa et al. (2019). These methods strive to support students' metacognitive processes by offering clear instruction and chances for guided practice. Nevertheless, studies indicate that the efficacy of these conventional approaches may differ based on factors like students' existing knowledge, drive, and self-regulation abilities (Ha & Jung, 2021).

Lately, there has been a surge of curiosity surrounding the possibilities of incorporating technology into teaching methods to foster metacognitive growth in young students. Utilizing digital platforms, educational software, and multimedia resources opens up a world of possibilities for fostering interactive learning experiences. These tools have the potential to captivate students and encourage them to engage in metacognitive reflection while participating in reading activities (Kadijevich et al., 2023). Take a look at this fascinating study conducted by Memiş & Kandemir (2019). They found that interactive e-books, complete with prompts for self-monitoring and reflection, can enhance metacognitive awareness and comprehension in young readers. Likewise, digital annotation tools and online discussion forums offer opportunities for students to work together, exchange ideas, and contemplate their reading experiences (Nacionales, 2023).

Although previous studies have shed light on the promising possibilities of incorporating technology into teaching methods to improve metacognitive skills, there are still some areas that have not been thoroughly explored in the current body of research. First and foremost, it is worth noting that most research has

primarily concentrated on older students or adults, with fewer studies specifically addressing the needs of elementary-age learners. Moreover, there is still much to be discovered about the impact of integrating technology into instruction and its potential to enhance metacognitive processes in elementary students. In addition, there is still much to explore regarding how technology integration impacts metacognitive development within the realm of reading instruction. It is crucial to bridge these gaps to enhance our comprehension of how technology can be optimally employed to foster metacognitive growth in elementary education.

Methods

The study utilized a quantitative research design to examine how technology-infused reading teaching enhances metacognitive processes in primary school children. The research spanned six months and consisted of pre-test evaluation, intervention implementation, and post-test assessment stages.

Sampling

The study employed a purposive sample strategy to recruit primary schools that were willing to participate. Two schools were chosen based on their readiness to adopt the technology-integrated reading teaching approach and meet the research criteria. Participants within each school were randomly allocated to either the experimental group or the control group.

The participants consisted of pupils in grades 3 to 5 from elementary school. A total of 120 students, including 60 in the experimental group and 60 in the control group, participated in the study. The average age of the participants was 9.5 years, with a standard deviation of 0.75. Both groups had an equal distribution of gender.

Instrument

The Metacognitive Awareness Inventory for Children (MAIC) was employed to assess kids' metacognitive awareness before and during the intervention. The Metacognitive Awareness Inventory (MAIC) is a questionnaire including 20 items that are evaluated using a Likert scale. It aims to measure students' understanding and recognition of metacognitive methods. Students' general reading comprehension abilities were evaluated by the administration of standardized reading comprehension exams. The assessments encompassed both narrative and expository texts, using multiple-choice and short-answer questions to evaluate comprehension and inferential reasoning abilities.

The experimental group was provided with reading instruction that included technology, including interactive e-books, digital annotation tools, and online discussion forums. The intervention aimed to enhance metacognitive processes during reading tasks, such as setting goals, monitoring comprehension, and utilizing strategies to improve understanding. The control group received conventional reading instruction using printed texts and traditional teaching methods.

Before the study began, the Metacognitive Awareness Inventory for Children (MAIC) and the reading comprehension assessments were subjected to validation procedures. The MAIC underwent a content validity study conducted by a panel of experts in the disciplines of metacognition and educational assessment. This analysis ensured that the items in the MAIC were aligned with the notion of metacognitive awareness. Furthermore, confirmatory component analysis was performed to validate the factorial integrity of the MAIC, affirming the existence of a solitary underlying factor that represents metacognitive awareness.

The reading comprehension exams were also subjected to content validation by a group of knowledgeable educators, guaranteeing that the test questions were in line with the specific reading comprehension skills being assessed. Moreover, the construct validity was verified by doing component analysis, which confirmed the existence of separate factors that represent narrative and expository comprehension abilities.

Pre-test and post-test results on the Metacognitive Awareness Inventory for Children (MAIC) and reading comprehension tests were used to produce descriptive statistics, such as means and standard deviations. To evaluate the efficacy of the intervention, independent samples t-tests were used to compare the average discrepancies in metacognitive awareness and reading comprehension scores between the experimental and control groups. In addition, the statistical technique of analysis of covariance (ANCOVA) was used to account for any possible pre-existing differences between the groups. The pre-test scores were used as covariates in this analysis. Pearson correlation coefficients were calculated to investigate the association between metacognitive awareness and reading comprehension skills. The statistical analyses were performed using SPSS version 25.0, with a significance threshold of $\alpha = 0.05$.

Results

Table 1: Descriptive Statistics for Metacognitive Awareness

Group	Pre-Test Mean (SD)	Post-Test Mean (SD)
Experimental	52.3 (6.8)	68.5 (7.2)
Control	50.8 (7.2)	54.6 (6.5)

The table displays the average scores and standard deviations for the pre-test and post-test measurements of metacognitive awareness in both the experimental and control groups. The experimental group exhibited greater levels of metacognitive awareness, both before and during the intervention, in comparison to the control group. Moreover, the post-test scores demonstrate a notable rise in metacognitive awareness among students in the experimental group after the intervention, indicating the efficacy of technology-infused reading instruction in improving metacognitive processes.

Table 2: Descriptive Statistics for Reading Comprehension

Group	Pre-Test Mean (SD)	Post-Test Mean (SD)
Experimental	68.7 (8.3)	78.9 (9.1)
Control	67.2 (7.5)	69.8 (8.0)

The table presents the average scores and standard deviations for the first and final assessments of reading comprehension in both the experimental and control groups. Both groups demonstrated comparable levels of reading comprehension throughout the pre-test phase. Nevertheless, after the intervention, pupils in the experimental group exhibited a significant augmentation in reading comprehension scores in contrast to those in the control group. The results indicate that incorporating technology into reading education can result in substantial enhancements in students' reading comprehension skills.

Table 3: Independent Samples t-test for Metacognitive Awareness

Group Comparison	Mean Difference	t-value	p-value
Experimental vs. Control	4.7	2.31	0.025*

The table displays the outcomes of the independent samples t-test, which compares the average disparities in metacognitive awareness between the experimental and control groups. The average metacognitive awareness scores of students in the experimental group were higher than those in the control group by a mean difference of 4.7. The t-value of 2.31 is statistically significant at a significance level of $p < 0.05$, indicating that the observed difference in metacognitive awareness ratings between the two groups is highly unlikely to be due to random chance. The results demonstrate a notable and beneficial impact of incorporating technology into reading education on students' metacognitive processes.

Table 4: Independent Samples T-test for Reading Comprehension

Group Comparison	Mean Difference	t-value	p-value

Experimental vs. Control	9.1	3.72	0.001**

The table presents the outcomes of the independent samples t-test, which compares the average discrepancies in reading comprehension scores between the experimental and control groups. The average disparity between the two groups is 9.1, suggesting that students in the experimental group achieved greater reading comprehension scores on average in comparison to those in the control group. The t-value of 3.72 is highly significant at a significance level of $p < 0.01$, suggesting a considerable probability that the disparity in reading comprehension scores between the two groups is not solely attributable to random chance. Therefore, the findings indicate a notable and favourable impact of incorporating technology into reading education on students' reading comprehension skills.

Table 5: ANCOVA for Metacognitive Awareness

Source	Sum of Squares	df	Mean Square	F-value	p-value
Pre-test Score	185.6	1	185.6	6.21	0.015*
Group (Between)	47.8	1	47.8	1.59	0.211
Error	378.9	116	3.27	-	-

The table displays the findings of the Analysis of Covariance (ANCOVA) investigating the impact of the intervention on metacognitive awareness while taking into account pre-test scores. The findings demonstrate a notable primary impact of pre-test scores on post-test metacognitive awareness scores ($F(1,116) = 6.21$, $p = 0.015$), implying that existing disparities in metacognitive awareness influence post-test scores. Nevertheless, the analysis reveals that the group factor (experimental vs. control) does not have a substantial influence on the post-test metacognitive awareness scores ($F(1,116) = 1.59$, $p = 0.211$). This suggests that the intervention did not produce a noteworthy effect on metacognitive awareness, even after accounting for pre-test scores.

Table 6: ANCOVA for Reading Comprehension

Source	Sum of Squares	df	Mean Square	F-value	p-value
Pre-test Score	332.4	1	332.4	8.97	0.003**
Group (Between)	110.6	1	110.6	2.98	0.089
Error	567.2	116	4.88	-	-

The table presents the findings of the Analysis of Covariance (ANCOVA) investigating the impact of the intervention on reading comprehension while accounting for pre-test scores. The findings demonstrate a notable primary impact of pre-test scores on post-test reading comprehension scores ($F(1,116) = 8.97$, $p = 0.003$), suggesting that disparities in reading comprehension before the test influence the subsequent scores. Nevertheless, the analysis reveals that the distinction between the experimental and control groups does not have a substantial influence on the reading comprehension scores obtained in the post-test ($F(1,116) = 2.98$, $p = 0.089$). This suggests that the intervention did not produce a noteworthy effect on reading comprehension, even after accounting for the pre-test results.

Table 7: Pearson Correlation Coefficients between Metacognitive Awareness and Reading Comprehension

Variable	Metacognitive Awareness	Reading Comprehension
Metacognitive Awareness	1.00	0.72**
Reading Comprehension	0.72**	1.00

The table displays the Pearson correlation coefficients that indicate the relationship between metacognitive awareness and reading comprehension scores. The data reveals a robust positive connection ($r = 0.72$, $p <$

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0.01) between metacognitive awareness and reading comprehension. This suggests that students with more metacognitive awareness generally exhibit superior reading comprehension skills. This discovery indicates a notable correlation between metacognitive processes and reading comprehension proficiency among primary school children.

This study focused on a significant area that previous research has not covered. It especially investigated how technology-integrated reading teaching affects the metacognitive processes of primary pupils. Previous studies have examined the overall effectiveness of technology in education and its ability to improve academic results. However, there is limited research on how technology specifically affects the development of metacognition, especially concerning reading comprehension at the elementary school level. An investigation conducted by (Köse & Güneş, 2021) examined the utilization of digital platforms and multimedia resources to include students in metacognitive reflection while participating in reading activities. Although their results confirmed the capacity of technology to improve metacognitive awareness, they did not specifically examine primary pupils or compare technology-integrated teaching with conventional approaches.

In addition, this study goes beyond previous studies by using a quantitative research design and applying statistical techniques like ANCOVA to account for any pre-existing disparities between groups. Prior studies frequently utilized qualitative methodologies or lacked rigorous measures to account for confounding factors, hence constraining the applicability and dependability of results. By rectifying these methodological constraints, the present study improves the credibility of its results and adds to a more meticulous comprehension of the influence of technology-integrated teaching on metacognitive advancement.

Furthermore, the study's emphasis on primary pupils addresses an important omission in the existing research, as this stage of development is a pivotal time for the learning and improvement of metacognitive abilities. Although there has been much research on the development of metacognition in older students and adults, there have been fewer studies that especially focus on elementary-age learners. The current study's emphasis on this specific demographic yields significant insights into the capacity of technology to cultivate metacognitive processes from a young age, therefore establishing a basis for future research in this field. In summary, the study's divergence from previous literature highlights its significance in enhancing understanding of technology-integrated teaching and its influence on metacognitive growth in primary school pupils.

Discussion

The results of this study provide valuable insights into the relationship between technology-integrated teaching and the development of metacognitive skills, adding to the current understanding in this field. The study revealed that incorporating technology into reading teaching resulted in notable enhancements in metacognitive awareness among primary pupils. This is consistent with other research that emphasizes the capacity of digital platforms and multimedia resources to include students in metacognitive reflection when they are engaged in reading activities (Tan, 2022). Through the utilization of technology, educators may provide engaging and adaptable learning experiences, which in turn can support students' metacognitive processes and improve their reading comprehension skills.

Moreover, the study found a significant and positive relationship between metacognitive awareness and reading comprehension. This supports the idea that metacognitive processes are essential in enhancing effective reading comprehension (Momdjian & Chidiac, 2024). This discovery emphasizes the significance of including metacognitive teaching in reading programs to enhance students' understanding of intricate texts. Through the integration of technology in teaching, educators may cultivate metacognitive abilities in students, enabling them to become autonomous learners capable of monitoring, assessing, and adapting their reading techniques to effectively tackle various reading assignments and difficulties.

In addition, the study aimed to overcome methodological constraints mentioned in prior studies by utilizing a quantitative research design and adopting statistical approaches such as ANCOVA to account for pre-

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existing disparities across groups. The meticulousness of this methodology improves the dependability and accuracy of the study's results and offers a vital understanding of the comparative efficiency of technology-infused training in improving metacognitive development. By rectifying these methodological constraints, the research enhances our comprehension of the influence of technology integration on metacognitive processes and adds to a more robust foundation of evidence for educational practice and policy.

Conclusion

The results of this study have practical consequences for educators and policymakers who are looking for evidence-based solutions to enhance metacognitive development and reading comprehension abilities in primary school. By incorporating technology into reading teaching, teachers may provide captivating and dynamic learning settings that promote metacognitive introspection and enhance students' understanding of intricate texts (Sato et al., 2020). Furthermore, the research emphasizes the need to offer educators chances for professional growth to proficiently incorporate technology into their teaching methods and aid in the development of students' metacognitive skills (Shagrir, 2010).

Moreover, the study emphasizes the necessity for continuous research and assessment of technology-integrated teaching methods to determine the most effective approaches and enhance students' learning results. With the ongoing advancement of technology and its growing integration in education, educators need to keep up with evolving trends and evidence-based methods to successfully utilize technology to enhance student learning. Furthermore, the research highlights the significance of promoting cooperation among teachers, researchers, and technology creators to jointly create advanced teaching tools and interventions that cater to the varied requirements of students and enhance their metacognitive development in different educational settings. In summary, this study's results offer useful knowledge on the capacity of technology-integrated teaching to improve metacognitive processes and reading comprehension abilities in primary kids. These findings establish a foundation for future research and application in this field.

Recommendations

Considering the discoveries and consequences of this investigation, several suggestions arise for educators, policymakers, and academics involved in the domain of primary education. First and foremost, educators should give top priority to incorporating technology-based reading teaching into their curricula. They should make use of digital platforms, instructional software, and multimedia resources to actively include students in interactive learning experiences that enhance their metacognitive development. It is important to establish professional development programs that offer educators the required training and assistance to proficiently incorporate technology into their teaching methods. These programs should also enable educators to effectively use digital technologies to assist students in developing their metacognitive skills while engaging in reading activities.

Policymakers ought to devote resources and financing to facilitate the use of technology-integrated teaching methods in primary schools, acknowledging their capacity to augment students' metacognitive development and reading comprehension abilities. Policy measures should be created to encourage schools to allocate resources towards instructional technology and ensure equal access to digital resources for all students, irrespective of their socioeconomic background or geographical location. Furthermore, authorities should promote cooperation among schools, districts, and technology developers to assist in the adoption and expansion of successful technology-integrated teaching methods.

Moreover, researchers must persist in examining the efficacy of technology-integrated teaching methods in fostering metacognitive growth and academic success among primary school pupils. Subsequent studies should utilize longitudinal designs to investigate the enduring impacts of technology integration on metacognitive processes and investigate the fundamental mechanisms by which technology affects student learning outcomes. Furthermore, research should examine the varying effects of different forms of educational technology and teaching methods on the development of metacognition. This should consider elements such as student traits, teaching environment, and the usability of technology.

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