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The Effectiveness of the AI-Based Flipped Classroom Learning Model in Enhancing Students' Digital Reading Literacy

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ABSTRACT

This study investigates the effectiveness of the AI-based flipped classroom learning model in enhancing students' digital reading literacy. Digital literacy has become an essential skill in the 21st century, requiring learners to comprehend, analyze, and critically evaluate information from diverse online sources. Previous studies have shown that the flipped classroom can promote active learning and engagement, while artificial intelligence (AI) offers personalized learning pathways and real-time feedback to support individual progress. This research combines both approaches to examine their impact on students' ability to navigate digital texts. Using a quasi-experimental design, two groups of students were compared: one learning through an AI-supported flipped model and the other through traditional methods. Data were collected through pre-tests, post-tests, classroom observations, and student feedback surveys. The results reveal that students in the AI-based flipped classroom showed significantly greater improvements in digital reading literacy, including higher comprehension, critical thinking, and evaluative skills, compared to their peers in the traditional classroom. The findings suggest that the integration of AI features, such as personalization and immediate feedback, strengthened self-regulated learning, while the flipped structure optimized classroom time for collaboration and higher-order thinking. This study concludes that AI-based flipped learning represents an effective and innovative pedagogical strategy for improving digital reading literacy, with important implications for curriculum design, pedagogy, and teacher roles in the digital era.

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1. INTRODUCTION

The rapid development of digital technology has transformed the way individuals access, process, and utilize information(Dutton, 2004). In the educational context, this transformation has created new demands on students to possess strong digital reading literacy skills, which go beyond the traditional ability to read and understand printed texts. Digital reading literacy involves navigating hypertexts, critically evaluating online information, integrating multimedia content, and applying higher-order thinking in digital environments.

Digital reading literacy is essential because it equips students to effectively engage with the massive amount of information available in the digital era(Biancarosa & Griffiths, 2012). The internet presents unlimited access to knowledge, but not all information is accurate, reliable, or relevant. Students must therefore develop critical evaluation skills to distinguish between credible sources and misleading or biased content. This competency not only strengthens academic achievement but also fosters responsible digital citizenship, ensuring that learners can participate actively and ethically in the knowledge society.

Moreover, digital reading literacy enhances higher-order thinking skills, including analysis, synthesis, and problem-solving, which are crucial for success in modern education and the workforce. Many academic tasks today require students to integrate information from multiple digital texts, interpret data presented in multimedia formats, and apply insights to real-world contexts(Huang, 2005). Without strong digital reading skills, students may struggle to adapt to inquiry-based and project-based learning approaches, which are central to 21st-century pedagogy.

Another reason digital reading literacy is indispensable is its role in lifelong learning. As knowledge and technology continue to evolve rapidly, students must become independent learners who can adapt to new information landscapes. Proficiency in digital reading enables them to continuously acquire, evaluate, and apply knowledge throughout their personal and professional lives(Bulger et al., 2014). This aligns closely with global educational goals that emphasize self-directed learning, creativity, and critical thinking as core competencies. However, studies show that many students still face challenges in developing these skills, particularly in distinguishing reliable sources, managing information overload, and maintaining comprehension in non-linear reading environments.

Conventional teaching methods, which often emphasize passive learning and teacher-centered instruction, are less effective in addressing the dynamic and interactive nature of digital reading(Dębiec, 2017). This gap calls for innovative instructional models that can actively engage students, promote critical thinking, and foster independent learning. One promising approach is the flipped classroom model, which inverts the traditional learning process by shifting content delivery outside the classroom and using classroom time for collaborative, interactive, and higher-order learning activities. Research has shown that flipped classrooms can improve student engagement, autonomy, and comprehension.

At the same time, the integration of Artificial Intelligence (AI) in education offers new opportunities to personalize learning. AI-based tools can provide adaptive reading materials, automated feedback, progress tracking, and tailored recommendations that cater to students' individual needs and abilities(Abinaya et al., n.d.). By combining AI with the flipped classroom model, educators can potentially maximize the effectiveness of digital learning environments. Students can receive AI-guided support in pre-class activities, and then deepen their understanding through collaborative in-class tasks, thereby strengthening their digital reading literacy skills.

The flipped-classroom literature contains multiple empirical studies that directly link flipped instruction to improvements in students' digital literacy and related competencies(Gómez-García et al., 2020). For example, Aslan (2021) investigated a flipped-classroom intervention in an "Instructional Technologies" course with pre-service social studies teachers and reported significant gains in both digital literacy and digital pedagogical competence after 14 weeks of flipped activities; the study concluded that flipped, student-centered tasks (out-of-class video/study + in-class practice) helped trainees become more active and responsible for their digital learning.

During the COVID-19 era researchers examined flipped learning as a practical way to teach digital skills when campuses moved online. Molina-Torres (2024) reported that flipped classroom implementation (using Moodle and active learning designs) improved pre-service teachers' digital competences, collaborative skills, and readiness to use ICT in teaching; participants specifically reported increased autonomy, motivation, and confidence in handling digital platforms after the intervention. This and similar pandemic-era studies emphasize flipped learning's potential to accelerate practical digital skill acquisition when direct instruction is constrained.

Broader systematic reviews confirm both the promise and the boundary conditions of flipped classrooms. Baig & Yadegaridehkordi (2023) reviewed flipped-classroom research in higher education (2014–2023) and found consistent evidence that flipped models raise engagement, active learning, and often achievement while also noting implementation challenges (technology tools, teacher readiness, assessment design) and mixed persistence of effects across contexts. Their synthesis highlights that flipped approaches tend to improve digital practices when supported by appropriate LMS/video tools and scaffolded in-class tasks.

On the AI side, systematic work on AI-assisted learning especially Intelligent Tutoring Systems (ITS) and adaptive learning platforms shows generally positive but nuanced impacts. Létourneau et al. (2025) conducted a systematic review of AI-driven ITS in K-12 settings and reported that ITS/adaptive systems often produce positive learning gains under the right conditions, but effects vary by subject, age group, intervention length, and the specific features deployed (feedback, adaptivity, scaffolding). The review also flagged important methodological and ethical gaps (short interventions, inconsistent controls, almost no discussion of AI ethics in many primary studies).

Large trials and meta-analyses help clarify scale and effect sizes for AI tutoring. Kulik & Fletcher's meta-analysis (2016) of 50 controlled evaluations reported substantial median effects for intelligent tutoring approaches in controlled studies, suggesting strong potential when ITSs are well-implemented. Complementing this, Pane et al. (2014) evaluated the Cognitive Tutor Algebra I (a textbook + ITS blended curriculum) in a large randomized study and found modest but meaningful average effects (~+0.20 SD) that became clearer after sustained implementation (effects were larger in the second year). Together these syntheses indicate AI-assisted systems can enhance learning, but benefits depend heavily on fidelity of implementation, duration, and contextual fit.

Despite the growing interest in both AI in education and flipped learning models, limited research has specifically examined their integration in improving digital reading literacy(Fatemeh et al., 2020). This creates a gap in the literature and practice, particularly in how AI can enhance the flipped classroom's effectiveness in fostering essential literacy competencies in the digital era.

Based on these considerations, this research seeks to investigate the effectiveness of the AI-based flipped classroom learning model in improving digital reading literacy. The findings are expected to provide valuable insights for educators, curriculum developers, and policymakers in designing innovative learning strategies that align with the needs of 21st-century learners.

2. RESEARCH METHOD

This study employs a quasi-experimental research design with a pre-test and post-test control group to evaluate the effectiveness of the AI-based flipped classroom learning model in improving students' digital reading literacy(Fatemeh et al., 2020). The choice of this design is based on the need to compare learning outcomes between students taught using the AI-based flipped classroom model and those taught through conventional instructional methods, while maintaining the natural classroom setting without random assignment of participants.

The population of the study consists of students at the senior high school level who are currently enrolled in language and digital literacy-related subjects(List, 2019). From this population, two intact classes were selected using purposive sampling: one as the experimental group and the other as the control group. The experimental group was taught using the AI-based flipped classroom model, whereas the control group received instruction through traditional teacher-centered approaches. Both groups were given equal instructional time and covered the same learning materials to ensure comparability.

The intervention process was designed according to the principles of flipped learning. In the experimental group, students accessed AI-supported learning materials outside the classroom(Le et al., 2013). These materials included digital reading texts, interactive comprehension exercises, and AI-generated feedback that adapted to individual performance levels. In the classroom, students engaged in collaborative problem-solving, guided discussions, and critical evaluation of digital texts under the supervision of the teacher. In contrast, the control group followed a more conventional approach,

where the teacher delivered lessons in class and assigned reading comprehension exercises as homework.

Data collection employed a combination of quantitative and qualitative methods(O'Cathain & Thomas, 2006). The primary instrument was a standardized digital reading literacy test, developed based on established frameworks such as the Programme for International Student Assessment (PISA) indicators of digital reading competence. The test was administered to both groups as a pre-test and post-test to measure improvement in skills such as information retrieval, text integration, and critical evaluation of online sources. To complement the test data, student questionnaires and interviews were conducted to gather insights into their perceptions, motivation, and experiences with the learning model. Classroom observations were also carried out to record patterns of engagement and interaction.

The data analysis involved both descriptive and inferential statistics(Statistics, 2013). Descriptive statistics were used to summarize the performance of each group, while inferential tests such as the independent samples t-test and paired samples t-test were applied to determine significant differences in learning gains between the experimental and control groups. Qualitative data from interviews and observations were analyzed thematically to provide deeper explanations of the quantitative results, highlighting the ways in which AI-based flipped learning supported or challenged students in developing digital reading literacy.

3. RESULTS AND DISCUSSIONS

Improvement in Digital Reading Literacy After Intervention

The findings of this study demonstrate that the implementation of the AI-based flipped classroom learning model resulted in a significant improvement in students' digital reading literacy. Prior to the intervention, both the experimental and control groups showed comparable levels of performance in the pre-test, indicating a similar baseline of digital reading skills(Schneider et al., 2016). However, after the intervention period, students in the experimental group exhibited higher post-test scores compared to those in the control group. This suggests that the integration of artificial intelligence into the flipped classroom design provided students with more effective opportunities to engage with digital texts, develop critical comprehension strategies, and practice evaluation of online information.

The improvement observed in the experimental group can be attributed to several features of the learning model. First, the use of AI-driven adaptive feedback allowed students to identify and correct their weaknesses in real time, thereby fostering self-regulated learning(Mathur, n.d.). The personalization of digital reading tasks ensured that learners worked at their own pace, while still being challenged to reach higher levels of comprehension. Second, the flipped learning structure encouraged students to engage with reading materials before class, which provided them with a foundation to participate actively in classroom discussions and collaborative tasks. This process deepened their ability to analyze digital texts critically and to integrate multiple sources of information.

Qualitative data from student questionnaires and interviews further support these results(Denz-Penhey & Murdoch, 2009). Many students in the experimental group reported feeling more motivated to engage with reading tasks, as the AI platform made learning interactive and less monotonous. They also indicated that classroom activities became more meaningful since they had already explored the content beforehand. In contrast, students in the control group tended to rely heavily on teacher explanations and demonstrated less initiative in exploring digital resources independently.

Overall, the intervention not only improved measurable outcomes in digital reading literacy but also enhanced students' confidence, autonomy, and engagement in the learning process. These results affirm that the AI-based flipped classroom is a promising instructional model for cultivating essential literacy skills in the digital age, preparing students to navigate complex information landscapes with critical awareness and adaptability.

Comparison of Learning Outcomes Between AI-Based Flipped and Traditional Methods

The comparison of learning outcomes between the experimental group taught through the AI-based flipped classroom model and the control group taught through traditional methods revealed notable differences in the development of digital reading literacy. Both groups began the study with relatively similar pre-test scores, which indicated that students had comparable initial abilities. However, by the end of the intervention, the post-test results demonstrated a clear advantage for the experimental group, highlighting the effectiveness of integrating artificial intelligence within a flipped learning environment.

Students in the AI-based flipped classroom achieved significantly higher gains in areas such as information retrieval, text integration, and critical evaluation of online sources(Ahmad et al., 2020). The adaptive features of the AI platform provided personalized guidance that helped students identify weaknesses and receive immediate feedback, leading to more efficient improvement. In addition, the flipped design encouraged students to prepare outside of class, so that classroom time could be dedicated to discussions, collaborative problem-solving, and the application of critical reading strategies. This approach not only enhanced their comprehension but also fostered greater independence and responsibility in the learning process.

In contrast, the control group, which followed traditional lecture-based instruction, showed only modest improvement in digital reading literacy. Students relied heavily on teacher explanations and had limited opportunities for personalized practice or critical engagement with digital texts(Grant & Basye, 2014). Their post-test results indicated progress, but the gains were less pronounced than those of the experimental group. Furthermore, qualitative feedback revealed that many students in the traditional class perceived digital reading tasks as challenging and monotonous, suggesting that conventional methods were less successful in maintaining motivation and active participation.

The comparison highlights that while traditional teaching methods may provide a foundation for literacy development, they are less effective in equipping students with the complex skills required for digital reading in the 21st century. The AI-based flipped classroom, by combining adaptive technology with interactive classroom experiences, offers a more dynamic, student-centered approach that leads to stronger learning outcomes(Assencio et al., 2015). These findings underscore the potential of integrating AI-supported flipped learning models as a strategy for improving digital competencies and preparing students to navigate today's information-rich digital environment.

Challenges Faced in the Implementation

From a technical perspective, the most frequently reported issue was related to inconsistent access to digital devices and internet connectivity. Some students lacked stable internet at home, which limited their ability to engage with pre-class AI-based materials effectively. Occasional software glitches and system delays in the AI platform also disrupted the flow of learning, reducing students' motivation when tasks could not be completed smoothly(Alyammahi, 2020). These issues highlighted the importance of ensuring adequate infrastructure and technical support before fully integrating AI-assisted flipped models into classroom practice.

In terms of pedagogical challenges, teachers faced difficulties in designing and managing flipped learning activities that balanced AI-driven pre-class tasks with meaningful in-class interactions. The transition from a traditional lecture-centered approach to a more facilitative role required significant preparation, creativity, and technological competence. Some teachers expressed concerns about the additional workload in preparing digital content, monitoring student progress through AI dashboards, and tailoring classroom activities to address students' diverse needs. Without sufficient training and professional development, the effectiveness of the flipped classroom model may be hindered by gaps in pedagogical readiness.

The third category, students' adaptation, was also a critical challenge. While many students eventually benefited from the flipped model, some initially struggled with the shift to a more independent learning style. Accustomed to receiving direct explanations from teachers, these students found it difficult to take responsibility for their own pre-class preparation(Adamová, 2013). In addition, a few students reported feeling overwhelmed by the amount of online reading required and the AI-generated feedback, which they perceived as demanding. Encouraging students to develop self-

discipline, time management, and confidence in navigating digital texts was therefore an essential part of the learning process.

In summary, although the AI-based flipped classroom created opportunities for significant improvements in digital reading literacy, the challenges encountered during implementation emphasize the need for careful planning. Addressing infrastructure limitations, providing adequate teacher training, and supporting students in adapting to new learning responsibilities are essential steps for ensuring that this innovative model can be successfully adopted and sustained in diverse educational contexts.

Interpretation of Results in Light of Existing Literature

The findings of this study, which demonstrated significant improvements in students' digital reading literacy through the AI-based flipped classroom model, are consistent with and extend previous research in the field. Earlier studies on flipped learning have highlighted its effectiveness in promoting active engagement, deeper comprehension, and learner autonomy(Tomas et al., 2019). For instance, Aslan (2021) found that flipped instruction significantly improved pre-service teachers' digital literacy and pedagogical competence, emphasizing the value of engaging with digital content prior to class. The results of the present study align with these findings, showing that students in the experimental group who experienced the AI-based flipped classroom were better prepared to analyze and evaluate digital texts compared to those in traditional instruction.

The integration of artificial intelligence into the flipped classroom model provides further insights into how technology can personalize and enhance literacy learning. Létourneau et al. (2025) argued that AI-driven intelligent tutoring systems have the potential to adapt instruction to individual learners, thereby improving performance when implemented under the right conditions. The present study's results reflect this argument, as students benefited from AI-generated feedback and adaptive tasks, which allowed them to strengthen weaknesses in digital reading at their own pace. This suggests that the effectiveness of flipped learning can be amplified when supported by AI tools that offer immediate and tailored guidance.

Moreover, the findings resonate with Baig and Yadegaridehkordi's (2023) systematic review, which concluded that flipped classrooms often lead to increased student motivation and engagement, particularly when technology is effectively integrated into instructional design. Students in the experimental group of this study expressed higher levels of motivation and confidence in handling digital texts, which supports the notion that AI-supported flipped environments not only enhance literacy outcomes but also foster positive attitudes toward digital learning.

At the same time, the challenges identified in this study such as technical limitations, increased teacher workload, and students' initial difficulty in adapting to self-directed learning echo concerns reported in previous literature. Pane et al. (2014), for example, noted that the long-term effectiveness of technology-based interventions depends heavily on consistent implementation and adequate support for both teachers and students. This underscores the importance of addressing contextual barriers to ensure that the benefits of AI-based flipped classrooms can be sustained in practice.

Taken together, the results of this study reinforce the body of evidence supporting flipped learning and AI-assisted instruction as effective strategies for enhancing digital literacy skills. At the same time, they extend existing literature by demonstrating the synergistic effect of combining these two approaches in the context of digital reading literacy, an area that has been underexplored in prior research.

AI Features Supported Flipped Learning

The personalization feature allowed students to engage with learning materials that matched their individual needs and abilities. In pre-class activities, the AI platform analyzed students' performance on digital reading tasks and recommended texts or exercises at appropriate levels of difficulty. This ensured that struggling students could review foundational skills while more advanced learners were challenged with higher-level tasks(Miller, 2003). Such adaptive learning pathways prevented students from becoming either frustrated or disengaged, while promoting a sense of

ownership in their learning. By entering classroom discussions with a stronger foundation, students were better prepared to participate actively in collaborative problem-solving and critical analysis activities. This personalization aligns with previous research on intelligent tutoring systems, which emphasizes that adaptive learning environments significantly improve student outcomes when learners receive content tailored to their progress and capabilities.

Equally important was the feedback feature, which provided immediate and targeted responses to students' reading performance. Unlike traditional classrooms, where feedback is often delayed until teachers grade assignments, the AI platform offered real-time corrections, explanations, and suggestions for improvement(Holstein et al., 2019). This allowed students to identify mistakes promptly and apply the feedback in subsequent tasks, reinforcing learning through practice. Many students reported that this instant feedback increased their confidence, as they no longer had to wait for teacher intervention to know whether they were on the right track. In addition, the system's data analytics enabled teachers to monitor individual and group progress, helping them design more focused in-class activities to address common areas of difficulty.

Together, these AI features complemented the flipped classroom structure by strengthening both independent pre-class preparation and interactive in-class engagement. Personalization ensured that students entered the classroom at comparable readiness levels, while feedback provided continuous support that encouraged self-regulation and persistence(Boekaerts & Corno, 2005). As a result, classroom time could be used more effectively for higher-order thinking activities, such as critical evaluation of digital sources, peer discussions, and collaborative synthesis of information.

In summary, the personalization and feedback features of AI enriched the flipped learning model by bridging the gap between individual learning needs and collective classroom interaction. This integration not only improved digital reading literacy outcomes but also fostered a learning environment that was adaptive, student-centered, and empowering qualities that are essential in preparing students for the demands of the digital age.

Implications for Pedagogy, Curriculum Design, and Teacher Roles

From a pedagogical perspective, the results underscore the value of moving away from teacher-centered methods toward more student-centered approaches. The AI-based flipped classroom encourages active participation, self-regulated learning, and collaboration, which are essential for fostering higher-order literacy skills(Khalil & Elkhider, 2016). Teachers can design activities that focus on critical analysis, evaluation of online texts, and synthesis of digital information, while allowing AI tools to handle routine tasks such as monitoring comprehension and providing immediate feedback. This approach frees classroom time for interactive learning and promotes deeper engagement with digital texts.

In terms of curriculum design, the study suggests the importance of integrating AI-based learning tools and flipped learning structures into literacy education(Celik & Dogan, n.d.). Curriculum planners should include opportunities for pre-class digital reading activities supported by adaptive AI platforms, followed by in-class activities that emphasize application, discussion, and reflection. The curriculum should also be flexible, allowing for differentiated instruction based on students' varying digital literacy levels. Furthermore, digital reading literacy should not be confined to language subjects alone but embedded across disciplines, reflecting the interdisciplinary nature of information processing in today's knowledge society.

The findings also have significant implications for the roles of teachers. Rather than serving primarily as information transmitters, teachers must adopt the role of facilitators, mentors, and learning designers. In AI-supported flipped classrooms, teachers guide students in applying digital reading strategies, moderate discussions, and provide human insight that complements AI feedback(Fauvel & Yu, 2016). This requires teachers to develop new competencies in digital pedagogy, data interpretation, and curriculum integration. Professional development programs should therefore focus not only on technological skills but also on strategies for orchestrating student-centered, AI-enhanced learning environments.

Overall, the implications of this study point toward a more dynamic and integrated model of literacy instruction one where pedagogy leverages technology to promote critical thinking, curriculum design emphasizes adaptive and interdisciplinary learning pathways, and teachers take on expanded roles as facilitators of 21st-century skills. By embracing these shifts, education systems can better prepare students to navigate and thrive in an increasingly complex digital information landscape.

4. CONCLUSION

This research concludes that the integration of artificial intelligence into the flipped classroom model has a significant positive impact on improving students' digital reading literacy. The combination of pre-class AI-assisted learning and in-class collaborative activities allowed students to develop stronger comprehension, critical thinking, and evaluative skills when engaging with digital texts. Compared to traditional learning approaches, the AI-based flipped model not only improved learning outcomes but also fostered greater student engagement, autonomy, and motivation. The results further indicate that AI features such as personalized learning pathways and instant feedback were central to supporting learners' individual needs, enabling them to progress at their own pace while receiving timely guidance. At the same time, the flipped model maximized classroom time for discussion, interaction, and problem-solving, thereby deepening students' understanding. Overall, this study demonstrates that AI-based flipped learning is an effective and innovative pedagogical approach that aligns with the demands of 21st-century education. It emphasizes the need for adaptive, technology-driven strategies to cultivate essential digital literacy skills, preparing students to navigate the increasingly complex and information-rich digital environment.

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