Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 8, 913-924
2025
Publisher: Learning Gate
DOI: 10.55214/2576-8484.v9i8.9489

Enhancing student engagement and learning outcomes in higher education through AI-supported flipped classrooms: A mixed-methods study

Cam Ai Tran[1], Hung Tran Van[2*], Ha Thu Thi Nguyen[3], Phuong Ba Le[4], Trung Tran[5,6]
[1]Nguyen Tat Thanh University, Vietnam; tacam@ntt.edu.vn (C.A.T.).
[2]University of Science and Education, The University of Danang, Vietnam; tvhung@ued.udn.vn (H.T.V.).
[3]Hai Duong University, Vietnam; uhdhanguyenthu76.edu@gmail.com (H.T.T.N.).
[4]Hanoi University of Industry, Viet Nam; phuonglb@haui.edu.vn (P.B.L.).
[5]Vietnam Academy for Ethnic Minorities, Vietnam; trungt1978@gmail.com (T.T.).
[6]University of Education, Vietnam National University, Vietnam.

Abstract: The integration of Artificial Intelligence (AI) in education has opened new opportunities for enhancing teaching models, notably the flipped classroom (FC). This study investigates the impact of an AI-supported flipped classroom model on student engagement and learning outcomes among university students in Vietnam. A mixed-methods approach was adopted, in which quantitative data were collected through pre- and post-tests, and qualitative insights were obtained via in-depth interviews. The AI tools used included automated video summarization, intelligent quiz generation, and personalized feedback systems integrated into the learning management system (LMS). Quantitative results from 210 undergraduate students revealed statistically significant improvements in academic performance and learner satisfaction. Specifically, the experimental group's post-test scores improved by an average of 2.1 points, compared to a 1.2-point improvement in the control group ($p < .001$), and emotional engagement increased by 16% over baseline. Thematic analysis of qualitative data highlighted increased motivation, self-regulated learning, and positive attitudes toward AI-enhanced instruction. The study concludes that the integration of AI in FC models fosters active learning, autonomy, and deeper engagement, contributing to improved educational effectiveness in higher education.

Keywords: *Artificial intelligence, Flipped classroom, Higher education, Personalized learning, Student engagement, Vietnam.*

1. Introduction

In recent years, the rapid advancement of digital technologies has fundamentally transformed the landscape of higher education. Among the emerging pedagogical innovations, the flipped classroom (FC) model and the integration of Artificial Intelligence (AI) into teaching and learning processes have garnered substantial attention [1, 2]. Both innovations represent a paradigm shift in how knowledge is delivered and acquired, with the potential to enhance learning experiences, promote learner autonomy, and foster engagement. The convergence of these two trends AI and flipped learning offers promising opportunities to revolutionize educational practice, particularly in university settings that are increasingly expected to cater to diverse student needs and equip learners with 21st-century skills [3].

The flipped classroom model, which inverts the traditional sequence of lectures and assignments, enables students to acquire foundational knowledge outside the classroom through digital resources and engage in higher-order learning activities during class time. This student-centered approach promotes active learning, collaboration, and the development of critical thinking skills [4, 5]. However, despite its pedagogical strengths, the effectiveness of the FC model is often contingent on students' preparedness, motivation, and access to meaningful feedback during self-paced learning activities [6]. These

History: Received: 11 June 2025; Revised: 14 June 2025; Accepted: 18 June 2025; Published: 16 August 2025
* Correspondence: tvhung@ued.udn.vn

limitations have motivated educators and researchers to explore the integration of AI tools into the FC model to address some of its shortcomings.

Artificial Intelligence, particularly in the form of intelligent tutoring systems, adaptive learning platforms, chatbots, and learning analytics dashboards, is increasingly being applied in educational contexts to deliver personalized, timely, and data-informed support to learners[7, 8]. AI systems can analyze student behaviors and performance in real time, offer customized content and feedback, automate assessments, and provide instructors with actionable insights into student learning progress. These capabilities make AI an ideal complement to the flipped classroom model, especially in addressing the challenges of pre-class preparation, engagement, and self-regulation [9].

Recent studies have begun to examine the individual effects of AI and FC on student learning outcomes and engagement. However, research investigating their integration remains limited, particularly in non-Western contexts where educational practices, student readiness, and institutional infrastructures may differ significantly from those in technologically advanced countries [10]. In Vietnam, where educational reform is increasingly prioritizing digital transformation and learner-centered pedagogies, there exists a fertile ground for exploring the implementation and impact of AI-enhanced flipped classrooms. Nonetheless, empirical evidence on the effectiveness of such integration in Vietnamese higher education is still scarce.

This study aims to address this gap by investigating how an AI-supported flipped classroom model affects student engagement and academic performance among undergraduate students in Vietnam. Specifically, it explores the extent to which AI tools—such as automated video summarizers, intelligent quizzes, chatbots, and personalized dashboards—can enhance the flipped classroom experience by improving students' learning outcomes and their engagement in both pre-class and in-class activities [11].

The research adopts a mixed-methods design, combining quantitative analysis of academic performance and engagement indicators with qualitative insights from student interviews. By employing both statistical data and narrative accounts, the study seeks to provide a comprehensive understanding of the affordances and limitations of AI-supported flipped learning. The results are intended to inform educators, curriculum designers, and policy makers interested in adopting innovative and effective instructional strategies in higher education.

Research questions:

RQ1: How does the integration of AI tools into the flipped classroom model influence student academic performance in a Vietnamese university context?

RQ2: In what ways does the AI-supported flipped classroom model affect student engagement across behavioral, cognitive, and emotional dimensions?

RQ3: What are students' perceptions of the usefulness and challenges of AI tools within the flipped learning environment?

By addressing these questions, this study contributes to the growing body of knowledge on technology-enhanced learning and offers practical recommendations for leveraging AI to support flipped classroom pedagogy in higher education. It also responds to broader educational goals of promoting learner autonomy, digital competence, and inclusive access to high-quality learning experiences in the digital age.

2. Literature Review

2.1. Flipped Classrooms in Higher Education

The flipped classroom (FC) model represents a paradigm shift from traditional teacher-centered instruction to a more student-centered approach that emphasizes active learning. In higher education, this model has become increasingly popular due to its capacity to foster critical thinking, collaboration, and deeper engagement. Traditionally, instructors delivered lectures during class, with students expected to complete exercises or assignments afterward. In the flipped classroom, students engage with pre-recorded lectures, readings, or multimedia content prior to attending class. This shift allows in-class time to be used more interactively for discussions, case studies, group activities, or problem-solving exercises [12, 13].

Research has consistently shown that the FC model leads to improved learning outcomes across various disciplines, including engineering, medicine, and education [4, 14]. For example, Foldnes [4] found that students in flipped classrooms outperformed their peers in traditional settings in both conceptual understanding and retention. Moreover, the FC model has been positively associated with increased student motivation, autonomy, and responsibility for learning, which are essential traits in the context of lifelong learning and professional development.

Despite these benefits, implementation challenges persist. These include student resistance due to unfamiliarity with the model, inadequate pre-class preparation, and the need for faculty to redesign curricula and assessments. Additionally, success in FC models often hinges on students' self-regulation and digital literacy skills factors that vary widely among learners in higher education. Therefore, while FC offers promise, its efficacy is influenced by contextual and instructional variables that merit further investigation [15].

2.2. Artificial Intelligence in Education

Artificial Intelligence (AI) has emerged as a transformative force in educational settings, offering innovative solutions to enhance learning efficiency, personalization, and engagement. AI in education includes a wide range of applications such as intelligent tutoring systems (ITS), adaptive learning environments, automated assessment systems, chatbots, and learning analytics platforms [16]. These technologies leverage machine learning algorithms and natural language processing to analyze student behavior, predict performance, and tailor content delivery to individual needs [7].

One of the most significant advantages of AI in education is its capacity to provide real-time, personalized feedback. Intelligent tutoring systems can simulate one-on-one human tutoring by identifying student misconceptions and delivering scaffolded guidance [17]. Adaptive learning platforms dynamically adjust the difficulty, pacing, and format of instructional content based on student responses and engagement metrics [18]. This level of personalization, often referred to as "precision education," has shown promising results in improving learning efficiency and reducing dropout rates.

Furthermore, AI can support instructors through automation of routine tasks such as grading, monitoring student progress, and identifying at-risk learners. Chatbots and virtual assistants enhance communication and accessibility by responding to frequently asked questions and providing instant clarification outside class hours [19]. Learning analytics, driven by AI, can offer actionable insights into how students interact with course materials, enabling data-informed pedagogical decisions.

However, the integration of AI in education is not without challenges. Ethical concerns related to data privacy, algorithmic transparency, and bias in machine learning models have gained attention [20]. Moreover, the effectiveness of AI tools varies significantly depending on their design, the pedagogical context, and the digital readiness of both instructors and students. As such, successful implementation requires not only technological infrastructure but also training, support, and ongoing evaluation.

2.3. Integrating AI into Flipped Classrooms

The convergence of AI and the flipped classroom model represents a forward-looking approach to education, blending the pedagogical strengths of active learning with the technological capabilities of personalization and automation. While both AI and FC have individually demonstrated positive impacts on learning, their integration has the potential to create a synergistic learning environment where students benefit from increased autonomy, immediate support, and data-driven guidance.

In an AI-supported flipped classroom, pre-class materials can be enhanced through adaptive video content that adjusts in length or depth based on learners' prior knowledge. AI tools can track student interaction with videos and readings, flag areas of difficulty, and generate individualized quizzes to reinforce comprehension before class [21]. During in-class activities, AI can facilitate peer collaboration through grouping algorithms based on learning profiles or provide real-time feedback through intelligent response systems [22].

Post-class, AI tools such as chatbots and dashboards can extend support beyond the classroom by answering queries, recommending additional resources, and helping students monitor their progress. From the instructor's perspective, learning analytics can offer insights into student engagement patterns and learning gaps, allowing for tailored instructional strategies and timely interventions.

Despite these promising developments, the integration of AI into FC models remains under-researched, especially in non-Western and resource-constrained contexts. Most studies have focused on high-income countries where access to digital infrastructure and AI tools is more prevalent. There is a need for empirical research examining the practical implementation, student acceptance, and pedagogical effectiveness of AI-enhanced FC in diverse educational settings, such as Vietnam [23].

Moreover, the success of this integration depends on the design and usability of the AI tools, the alignment with learning objectives, and the extent to which students and instructors are trained to utilize them effectively. Addressing these issues can maximize the benefits of AI in flipped instruction and contribute to more inclusive, scalable, and personalized higher education models.

To explore these questions, the study employs a mixed-methods design, integrating both quantitative and qualitative data to assess the effects of the AI-supported flipped classroom model.

3. Methodology

3.1. Research Design

A convergent mixed-methods approach was employed to gather comprehensive data on the impact of the AI-supported FC model. Specifically, the quantitative component consisted of pre- and post-tests measuring academic performance, while the qualitative component was based on in-depth interviews designed to explore student experiences and perceptions. This methodological combination enabled triangulation of results, enhancing the reliability and richness of the findings [24, 25].

3.2. Participants

A total of 210 undergraduate students participated in the study. Participants were recruited from a large public university in Vietnam using stratified random sampling, ensuring balanced representation across academic years and departments within the Faculty of Education. The participants were randomly assigned to two groups: the experimental group (n=105), which experienced the AI-supported FC model, and the control group (n=105), which experienced a traditional FC model without AI integration. While the sampling was limited to one institution, the demographic diversity of the participants enhances the internal validity of the study.

3.3. Intervention Design

The intervention applied in this study was the implementation of an AI-supported flipped classroom model tailored for undergraduate students enrolled in an educational technology course. The intervention spanned a full academic semester and was designed to support both pre-class and in-class learning processes through the integration of multiple AI tools within a learning management system (LMS).

Before class sessions, students in the experimental group accessed AI-generated video summaries, which condensed lengthy lecture videos into personalized, digestible segments based on learners' previous interactions and performance. These summaries enabled more focused pre-class preparation and helped accommodate diverse learning paces. Alongside video content, intelligent quiz generators created individualized quizzes that adapted in difficulty and scope depending on the student's prior responses, promoting deeper understanding and retention.

During class sessions, students engaged in collaborative problem-solving and interactive discussions. The AI system provided instructors with real-time analytics dashboards, offering insights

into student preparation levels and identifying common misconceptions. This allowed for dynamic adjustment of in-class activities to better address learning needs.
After class, AI-powered chatbots were made available 24/7 to answer questions, clarify concepts, and suggest additional learning resources. Additionally, students accessed learning analytics dashboards that visualized their performance trends, engagement history, and recommended personalized study paths. These tools supported self-regulated learning and continuous improvement.
By contrast, the control group experienced a traditional flipped classroom model without AI support. They were provided with static video lectures and generic quizzes, and had no access to adaptive tools or automated feedback mechanisms.

3.4. Data Collection Instruments

Data were collected using a combination of quantitative and qualitative instruments designed to capture both objective performance outcomes and subjective learner experiences. First, pre- and post-tests were administered to both the experimental and control groups to assess academic improvement over the course of the intervention. The tests were designed to measure conceptual understanding, problem-solving ability, and content retention aligned with course objectives.

To evaluate student engagement, a validated engagement survey was distributed at the end of the intervention. The survey measured three core dimensions of engagement: behavioral (e.g., participation, attendance, task completion), cognitive, and emotional. Responses were recorded on a five-point Likert scale ranging from "Strongly Disagree" to "Strongly Agree."

In addition to the surveys, qualitative data were gathered through semi-structured interviews with 20 students from the experimental group. Interview questions explored students' perceptions of the AI tools, their influence on learning motivation and self-regulation, and the overall usability and support provided by the system. The interviews were audio-recorded, transcribed, and thematically analyzed using NVivo software.

Learning analytics data from the AI-enhanced LMS such as quiz completion rates, chatbot usage logs, and dashboard interaction histories were also reviewed to triangulate findings and validate student-reported engagement behaviors. This multi-method approach provided a comprehensive understanding of the effectiveness and reception of the AI-supported flipped classroom model.

3.5. Data Analysis

The study employed both quantitative and qualitative data analysis methods to ensure a robust and comprehensive interpretation of results. Quantitative data, including pre- and post-test scores and engagement survey responses, were analyzed using SPSS (Statistical Package for the Social Sciences) [26]. Descriptive statistics (mean, standard deviation) were calculated for all variables, and paired sample t-tests were conducted to assess the significance of differences in academic performance before and after the intervention. One-way ANOVA tests were used to compare engagement levels between experimental and control groups across the three dimensions: behavioral, cognitive, and emotional.

Effect sizes (Cohen's d) were calculated to interpret the magnitude of the observed differences, with thresholds of 0.2, 0.5, and 0.8 representing small, medium, and large effects, respectively. Reliability analyses (Cronbach's alpha) were performed on the engagement survey to ensure internal consistency of the scales.

For the qualitative component, interview transcripts were analyzed thematically using NVivo software. The analysis followed a six-step coding process: familiarization with the data, initial code generation, searching for themes, reviewing themes, defining and naming themes, and producing the report. Codes were both deductive, based on the interview questions, and inductive, allowing for the emergence of unanticipated themes. Representative quotes were selected to illustrate key findings and provide depth to the quantitative results.

To ensure credibility and triangulation, learning analytics from the LMS were used to cross-check and validate student-reported behaviors. These analytics included data on quiz participation, time-on-task, chatbot usage frequency, and dashboard engagement metrics. The integration of these multiple data sources enabled a multi-faceted understanding of how students interacted with the AI-supported flipped classroom environment, thereby enhancing the validity of the study's conclusions.

To further strengthen the interpretation of findings, the results of the One-way ANOVA tests are summarized in the following table, which compares the engagement dimensions between the experimental and control groups.

Table 1.
One-way ANOVA Results: Comparison of Engagement Dimensions.

Engagement Dimension	Group	Mean	SD	F-value	p-value	Interpretation
Behavioral Engagement	Experimental	4.35	0.48	15.21	< .001	Significant difference (p < .001)
	Control	3.68	0.55			
Cognitive Engagement	Experimental	4.41	0.46	18.75	< .001	Significant difference (p < .001)
	Control	3.64	0.58			
Emotional Engagement	Experimental	4.28	0.51	13.47	< .001	Significant difference (p < .001)
	Control	3.70	0.60			

In addition, assumptions underlying the statistical tests (e.g., normality, homogeneity of variance) should be tested and reported to affirm the validity of the inferences drawn. Lastly, although the integration of learning analytics adds a valuable layer of triangulation, further validation using external evaluators or longitudinal performance metrics could enhance reliability over time.

4. Results

4.1. Learning Outcomes

The quantitative results of the pre- and post-test assessments revealed a significant difference in learning outcomes between the experimental and control groups. Students in the AI-supported flipped classroom (FC) group achieved a mean post-test score of 8.4 (SD = 0.65), while those in the traditional FC group scored 7.1 (SD = 0.72), with a p-value < .001 and a large effect size (Cohen’s d = 0.82). This strong effect indicates that the AI-supported instructional approach had a substantial influence on students' academic achievement [27].

An analysis of individual score improvements from pre-test to post-test also revealed more pronounced gains in the experimental group, with an average increase of 2.1 points compared to 1.2 points in the control group. Notably, students who initially scored below average showed the greatest improvements, suggesting that AI tools may be especially beneficial for supporting struggling learners through personalized feedback and adaptive learning pathways [28].

The results support the hypothesis that AI-enhanced flipped instruction allows for more effective pre-class preparation and in-class application, which collectively boost knowledge retention. AI-driven adaptive quizzes targeted students’ specific learning gaps and provided immediate feedback, allowing students to correct misconceptions and build confidence in their understanding. Furthermore, students in the experimental group reported higher self-efficacy levels and greater satisfaction with their learning process.

4.2. Student Engagement

Student engagement was examined across three domains behavioral, cognitive, and emotional using validated engagement scales. The survey results demonstrated a clear improvement in overall engagement levels in the AI-supported FC group compared to the control group.

The results of the One-way ANOVA analysis are presented in Table 1 (see above), showing statistically significant differences across all three dimensions. It is important to note that while One-way ANOVA was used to compare differences in engagement levels between the two groups, paired sample t-tests could also be conducted within each group to assess pre- and post-intervention changes in engagement. These t-tests may provide additional insight into the within-group development of behavioral, cognitive, and emotional engagement dimensions. However, since the primary focus of this study was to compare the effectiveness of the AI-supported FC model versus the traditional FC model, One-way ANOVA remains the more appropriate statistical method to emphasize between-group differences in post-intervention results.

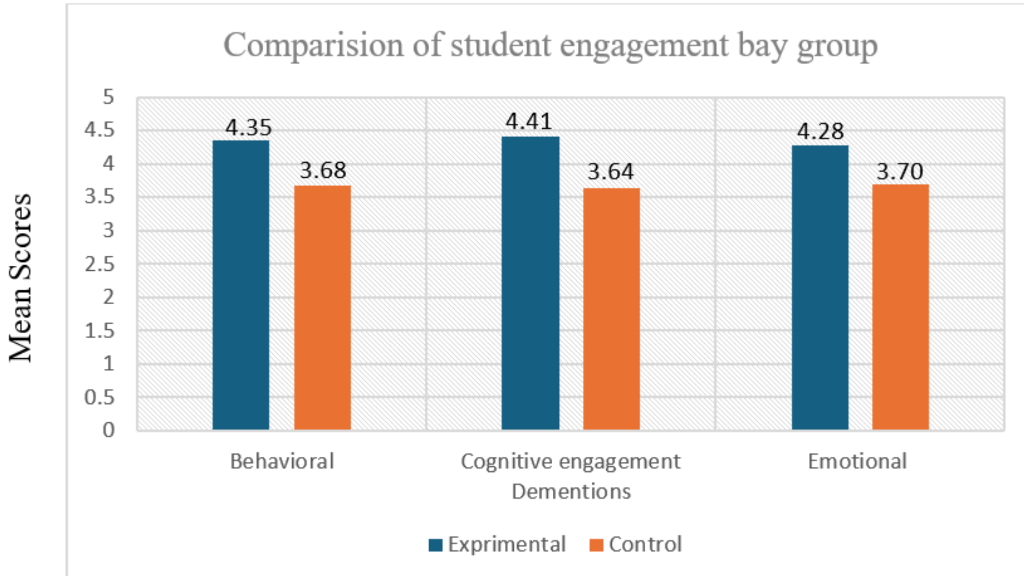

Figure 1.
t-test results.

- Behavioral engagement improved by 18%. Students exhibited higher participation in pre-class activities, submitted assignments more punctually, and demonstrated increased involvement during in-class problem-solving sessions. The automated reminders and progress tracking features built into the learning dashboard were cited as major contributors to this behavior.
- Cognitive engagement increased by 21%. Students indicated that they spent more time thinking critically about the content, asked more thoughtful questions in class, and applied concepts more independently. The intelligent quiz systems encouraged students to engage with content beyond superficial recall, stimulating analytical thinking and deep processing.
- Emotional engagement rose by 16%. Students expressed a stronger sense of belonging and enthusiasm toward the course, which they attributed to the responsiveness of AI chatbots and the personalization of learning materials. Many described a greater emotional connection to learning because of the AI tools' ability to "understand" their individual needs and provide relevant support.

In future studies, it may be beneficial to present both t-test and ANOVA results in parallel, especially when investigating both within-group and between-group changes. While this study primarily focuses on between-group comparisons using ANOVA, incorporating pre-post engagement scores analyzed through paired t-tests could offer further validation of the intervention's impact. A comprehensive table summarizing both statistical methods and their outcomes would help reinforce the robustness of the findings.

The experimental group also reported significantly higher levels of satisfaction with their learning experience ($M = 4.5$ on a 5-point Likert scale) compared to the control group ($M = 3.9$). Students commented on the novelty and effectiveness of the AI tools in keeping them engaged and motivated, particularly during independent learning phases.

ISSN: 2576-8484
Vol. 9, No. 8: 913-924, 2025
DOI: 10.55214/2576-8484.v9i8.9489

4.3. Student Perceptions

In-depth interviews were conducted with 20 students from the experimental group to gain qualitative insights into their experiences. Three dominant themes emerged: increased motivation, self-regulated learning, and enhanced academic support.

- Increased Motivation: Students noted that the AI tools made learning more enjoyable and rewarding. Personalized quiz feedback and gamified elements in the dashboard (e.g., badges, completion rates, and mastery levels) encouraged sustained engagement. One student remarked: "I wanted to beat my previous score on the AI quiz not because I had to, but because it felt like a game."
- Self-regulated Learning: The learning analytics dashboard provided students with real-time insights into their progress. This feature encouraged goal setting, planning, and reflection. Many students reported using the dashboard to identify weak areas and proactively review materials. They appreciated that they could study at their own pace, without waiting for instructor feedback.
- Enhanced Support: Students appreciated the availability of AI chatbots, especially for addressing common questions and offering study tips. This tool reduced students' dependence on instructors, which was particularly helpful during evenings or weekends. One interviewee noted: "Even when I felt stuck at night, the chatbot gave me instant help it was like having a personal tutor."

Additionally, students expressed trust in the AI system's fairness and accuracy, especially regarding automated grading and progress tracking. However, a few students suggested improvements, such as increasing the chatbot's natural language capabilities and expanding the variety of feedback types offered.

These perceptions reveal a generally positive reception of AI integration in the flipped classroom model. Students viewed the AI tools not as replacements for teachers, but as powerful supplements that provided structure, feedback, and encouragement. The qualitative data aligns with the quantitative results, strengthening the overall validity of the study's findings.

Taken together, the analyses of learning outcomes, engagement levels, and student perceptions provide robust evidence for the effectiveness of the AI-supported flipped classroom. These results not only demonstrate the pedagogical value of integrating AI into instructional design but also highlight the potential for AI tools to foster greater student autonomy, motivation, and academic success

5. Discussion

The findings of this study affirm the growing potential of AI-enhanced flipped classrooms (FCs) in fostering meaningful learning experiences for university students. The results from both the quantitative and qualitative data support the notion that AI, when effectively integrated into instructional design, can significantly elevate student academic performance, engagement, and motivation.

First and foremost, the improved learning outcomes observed in the experimental group highlight the efficacy of AI-supported learning tools in promoting content mastery and cognitive development. The statistically significant improvement in post-test scores, especially among students who initially performed below average, indicates that AI features such as adaptive quizzes and personalized feedback systems were instrumental in scaffolding student understanding. These findings are consistent with prior studies on intelligent tutoring systems and adaptive learning environments, which have shown that real-time, personalized interventions can support differentiated instruction and mitigate learning gaps [7].

The increase in student engagement across behavioral, cognitive, and emotional domains further demonstrates the value of integrating AI into flipped learning models. Behavioral engagement was positively influenced by the LMS-integrated AI functions such as automated reminders and progress trackers, which nudged students toward timely task completion. Cognitive engagement was notably enhanced using AI-generated quizzes that adapted to learners' performance and encouraged deeper processing of content. Meanwhile, emotional engagement improved using responsive AI chatbots, which offered a sense of support and accessibility beyond traditional classroom hours.

These findings align with contemporary educational psychology theories, such as self-determination theory, which emphasizes the importance of autonomy, competence, and relatedness in promoting student motivation. The AI tools implemented in this study not only helped fulfill these psychological needs but also created a feedback-rich learning ecosystem in which students were empowered to take ownership of their learning journeys.

The qualitative data provided additional insights into how students experienced the AI-supported flipped classroom model. Student narratives illustrated that the gamified learning dashboards and real-time feedback mechanisms helped maintain motivation and attention. More importantly, the AI system facilitated the development of self-regulated learning skills such as goal setting, monitoring progress, and adjusting learning strategies which are essential for academic success in higher education and lifelong learning.

The integration of AI tools also benefited instructors by offering learning analytics that informed instructional decisions. Educators could track student progress more precisely and identify areas requiring reinforcement, thereby increasing the responsiveness of their teaching. This data-driven approach contributed to a more agile and adaptive instructional environment, aligning with the principles of personalized education.

Despite these positive outcomes, some limitations were also evident. A few students encountered challenges in interpreting AI-generated feedback or navigating the chatbot interface, suggesting a need for clearer design and better user onboarding. Additionally, there were concerns regarding over-reliance on automated systems, which, if not carefully balanced, might reduce opportunities for human interaction core component of effective learning environments.

Another issue that emerged was the digital divide. While the AI-supported FC model provided scalable solutions, its effectiveness may be limited in contexts where students lack reliable access to devices or the internet. Addressing infrastructure and accessibility concerns is therefore crucial to ensuring the equitable implementation of such technologies.

From a theoretical perspective, the study reinforces models such as the TAM and UTAUT, which posit that perceived usefulness and ease of use influence the adoption of technological innovations. The overwhelmingly positive perceptions expressed by students in this study suggest that when AI tools are perceived as supportive and intuitive, they can gain high levels of acceptance and engagement.

Overall, this research contributes to the growing evidence based on the pedagogical affordances of AI in higher education. It underscores the importance of designing AI-enhanced learning environments that are not only technically robust but also pedagogically sound and learner-centered. As educational institutions continue to explore digital transformation, integrating AI into flipped classroom models represents a promising strategy to foster personalized, engaging, and effective learning experiences at scale.

Future research could expand upon these findings by investigating the long-term effects of AI-enhanced FC models across disciplines and student populations. It would also be beneficial to explore instructor perspectives and training needs to support successful implementation. Finally, more studies are needed to examine the ethical dimensions of AI in education, including issues related to data privacy, transparency, and algorithmic bias.

6. Limitations

Although this study contributes valuable insights into the implementation of AI-enhanced flipped classrooms, several limitations should be acknowledged. First, the research was conducted within a single course at one public university in Vietnam, which may restrict the generalizability of the findings. Future studies should consider multi-site investigations across various disciplines and institutions to enhance external validity.

Second, the duration of the intervention was limited to one academic semester. While short-term outcomes were promising, long-term effects on learning retention, knowledge transfer, and sustained engagement remain unknown. Longitudinal studies are needed to assess the durability of these impacts over time.

Third, the study relied on self-reported engagement measures and perceptions, which may be subject to bias or inaccuracies. Although learning analytics and interviews were used to triangulate results, more objective measures such as behavioral tracking or physiological data could offer deeper insights into student engagement patterns.

Fourth, the research focused solely on students' perspectives. Incorporating instructor feedback could provide a more holistic understanding of the practical challenges and pedagogical adjustments involved in integrating AI tools. Moreover, it would be valuable to investigate the support and training required by faculty to effectively adopt and sustain AI-enhanced models.

Lastly, the study did not deeply explore ethical concerns surrounding AI usage in education. While some students expressed concerns about fairness and transparency, these were not systematically examined. Future research should address the ethical, legal, and societal implications of AI in learning environments, including data privacy, algorithmic bias, and informed consent.

Recognizing these limitations offers opportunities for refinement and expansion in subsequent studies aimed at optimizing AI-supported flipped classroom practices.

7. Conclusion

This study examined the integration of Artificial Intelligence (AI) into the flipped classroom (FC) model and its impact on student learning outcomes and engagement in a Vietnamese higher education context. Drawing on both quantitative and qualitative data, the findings provide compelling evidence that AI-supported FC environments can enhance academic achievement, promote deeper engagement, and support self-regulated learning among university students.

The significant improvement in post-test scores and the high levels of behavioral, cognitive, and emotional engagement observed in the experimental group affirms the pedagogical potential of combining AI with active learning strategies. AI tools such as adaptive quizzes, chatbots, learning dashboards, and video summarizers were shown to personalize the learning experience, provide timely feedback, and guide learners in tracking their progress all of which contributed to increased motivation, autonomy, and academic success.

Furthermore, student feedback highlighted the usability, accessibility, and motivational benefits of AI integration. Learners perceived the AI tools not as substitutes for human instruction but as supportive, interactive companions that enriched their learning journeys. This suggests that well-designed AI systems, when aligned with instructional goals, can foster learner-centered environments that scale personalization without sacrificing interaction.

While the study revealed strong educational benefits, it also acknowledged limitations related to sample size, duration, data sources, and ethical considerations. These limitations offer valuable directions for future research. Subsequent studies should explore long-term effects, cross-disciplinary applications, instructor perspectives, and the responsible design of AI systems in education.

In conclusion, this study contributes to the growing body of literature on AI-enhanced pedagogies by demonstrating how AI can be harnessed to strengthen the flipped classroom model. As educational institutions navigate digital transformation, this integrated approach offers a promising pathway toward more inclusive, adaptive, and effective teaching and learning in higher education.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

References

[1] M. I. Baig and E. Yadegaridehkordi, "Flipped classroom in higher education: A systematic literature review and research challenges," *International Journal of Educational Technology in Higher Education*, vol. 20, no. 1, p. 61, 2023. https://doi.org/10.1186/s41239-023-00430-5

[2] L. R. Murillo-Zamorano, J. Á. L. Sánchez, and A. L. Godoy-Caballero, "How the flipped classroom affects knowledge, skills, and engagement in higher education: Effects on students' satisfaction," *Computers & education*, vol. 141, p. 103608, 2019. https://doi.org/10.1016/j.compedu.2019.103608

[3] L.-K. Ng and C.-K. Lo, "Flipped classroom and gamification approach: Its impact on performance and academic commitment on sustainable learning in education," *Sustainability*, vol. 14, no. 9, p. 5428, 2022. https://doi.org/10.3390/su14095428

[4] N. Foldnes, "The flipped classroom and cooperative learning: Evidence from a randomised experiment," *Active Learning in Higher Education*, vol. 17, no. 1, pp. 39-49, 2016. https://doi.org/10.1177/1469787415616726

[5] S. McLean and S. M. Attardi, "Sage or guide? Student perceptions of the role of the instructor in a flipped classroom," *Active Learning in Higher Education*, vol. 24, no. 1, pp. 49-61, 2023. https://doi.org/10.1177/1469787418793725

[6] S. Park, H. Kaplan, and R. Schlaf, "Interdisciplinary flipped learning for engineering classrooms in higher education: Students' motivational regulation and design achievement," *Computer Applications in Engineering Education*, vol. 26, no. 3, pp. 589-601, 2018. https://doi.org/10.1002/cae.21910

[7] O. Zawacki-Richter, V. I. Marín, M. Bond, and F. Gouverneur, "Systematic review of research on artificial intelligence applications in higher education–where are the educators?," *International Journal of Educational Technology in Higher Education*, vol. 16, no. 1, pp. 1-27, 2019. https://doi.org/10.1186/s41239-019-0171-0

[8] C. K. Lo and K. F. Hew, "A review of integrating AI-based chatbots into flipped learning: New possibilities and challenges," *Frontiers in Education*, vol. 8, p. 1175715, 2023. https://doi.org/10.3389/feduc.2023.1175715

[9] S. Uchiyama, K. Umemura, and Y. Morita, "Large language model-based system to provide immediate feedback to students in flipped classroom preparation learning," *arXiv preprint arXiv:2307.11388*, 2023.

[10] N. T. Hang, "The role of adoption, ease of use and teachers' experience of artificial intelligence on teaching effectiveness: moderating role of student interest," *Journal of Pedagogical Research*, vol. 8, no. 4, pp. 16-29, 2024. https://doi.org/10.33902/JPR.202428342

[11] W. Peng, Y. Yang, Z. Zhang, and T. J.-J. Li, "GLITTER: An AI-assisted platform for material-grounded asynchronous discussion in flipped learning," in *Proceedings of the ACM Symposium on User Interface Software and Technology (UIST)*, 2025.

[12] P. Strelan, A. Osborn, and E. Palmer, "The flipped classroom: A meta-analysis of effects on student performance across disciplines and education levels," *Educational Research Review*, vol. 30, p. 100314, 2020. https://doi.org/10.1016/j.edurev.2020.100314

[13] J. E. McLaughlin, P. J. White, J. Khanova, and E. Yuriev, "Flipped classroom implementation: A case report of two higher education institutions in the United States and Australia," *Computers in the Schools*, vol. 33, no. 1, pp. 24-37, 2016. https://doi.org/10.1080/07380569.2016.1137734

[14] J. L. Bishop and M. A. Verleger, "The flipped classroom: A survey of the research," in *Proceedings of the 120th American Society for Engineering Education (ASEE) Annual Conference & Exposition*, 2013.

[15] G. Akçayır and M. Akçayır, "The flipped classroom: A review of its advantages and challenges," *Computers & Education*, vol. 126, pp. 334-345, 2018. https://doi.org/10.1016/j.compedu.2018.07.021

[16] H. Jang, M. Park, and H. Oh, "Improved socialtaxis for information-theoretic source search using cooperative multiple agents in turbulent environments," *Expert Systems with Applications*, vol. 225, p. 120033, 2023. https://doi.org/10.1016/j.eswa.2023.120033

[17] E. Kochmar, D. D. Vu, R. Belfer, V. Gupta, I. V. Serban, and J. Pineau, "Automated personalized feedback improves learning gains in an intelligent tutoring system," presented at the In International Conference on Artificial Intelligence in Education (pp. 140-146). Cham: Springer International Publishing, 2020.

[18] I. Gligorea, M. Cioca, R. Oancea, A.-T. Gorski, H. Gorski, and P. Tudorache, "Adaptive learning using artificial intelligence in e-learning: A literature review," *Education Sciences*, vol. 13, no. 12, p. 1216, 2023. https://doi.org/10.3390/educsci13121216

[19] R. I. E. Saragih, "AI-powered education: Transforming learning through personalized and scalable solutions," *International Journal of Information System and Innovative Technology*, vol. 3, no. 2, pp. 1-9, 2024. https://doi.org/10.63322/qm9dk118

[20] A. Nguyen, H. N. Ngo, Y. Hong, B. Dang, and B.-P. T. Nguyen, "Ethical principles for artificial intelligence in education," *Education and Information Technologies*, vol. 28, no. 4, pp. 4221-4241, 2023. https://doi.org/10.1007/s10639-022-11316-w

[21] A. Triantafyllidis, K. Leftheriotis, M. Kotsovoulou, T. Cirstea, and G. Vranopoulos, "Introducing AI in flipped classroom: A preliminary study," *EDULEARN24 Proceedings*, pp. 8828–8835, 2024. https://doi.org/10.21125/edulearn.2024.2129

[22] C. W. Tan, "Large language model-driven classroom flipping: Empowering student-centric peer questioning with flipped interaction," *arXiv preprint arXiv:2311.14708*, 2023.

[23] N. T. T. Huyen, "Applying flipped classroom model: A case study in teaching english for academic purposes at international school, Vietnam National University Hanoi," *International Journal of Social Science and Education Research Studies*, vol. 4, no. 7, pp. 1–9, 2024. https://doi.org/10.55677/ijssers/V04I7Y2024-02

[24] E. Cabı and H. Türkoğlu, "The impact of a learning analytics based feedback system on students' academic achievement and self-regulated learning in a flipped classroom," *International Review of Research in Open and Distributed Learning*, vol. 26, no. 1, pp. 175-196, 2025. https://doi.org/10.19173/irrodl.v26i1.7924

[25] S. Ray and D. P. Sikdar, "AI-driven flipped classroom: Revolutionizing education through digital pedagogy," *Psychology*, vol. 7, no. 2, pp. 169-179, 2024. https://doi.org/10.52589/BJELDP-LTDJFLIH

[26] Z. Lysaght and G. Cherry, *Using SPSS and NVivo to conduct mixed-methods analysis collaboratively online: Challenges, opportunities, and lessons learned. 1 oliver's yard, 55 city road.* London EC1Y 1SP United Kingdom: SAGE Publications, Ltd, 2022.

[27] A. A. Kehinde-Awoyele, W. A. Adeowu, and B. Oladejo, "Enhancing classroom learning: the impact of ai-based instructional strategies on student engagement and outcomes," *International Journal of Research and Innovation in Social Science*, vol. 8, no. 3s, pp. 5732-5742, 2024. https://doi.org/10.47772/IJRISS.2024.803429S

[28] R. D. Villarosa Jr, "Exploring college students' awareness and use of AI-enhanced flipped classroom models: Impacts on learning outcomes and skills development," *International Research Journal of Science, Technology, Education, & Management*, vol. 4, no. 4, pp. 99-113, 2024. https://doi.org/10.5281/zenodo.14744850