

# Reimagining Student Engagement in Metaverse-Flipped Classroom using Spatial.io

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## ABSTRACT

This research investigates the use of the Spatial.io metaverse platform within a flipped classroom model to improve student engagement, specifically focusing on participation, attentiveness, and collaboration among secondary school students. Instructors frequently seek innovative methods to engage students, even within the flexible structure of a flipped classroom. Platforms like Spatial.io, with their immersive metaverse features, offer unique environments that can significantly aid students' participation in learning interactions. The study involved 15 students from a Form 2 Basic Computer Science class in Malaysia, employing a mixed-methods approach that integrated quantitative survey data with qualitative thematic analysis. The results indicate that the use of Spatial.io significantly enhanced student engagement in learning due to its interactive features. Quantitatively, students reported high mean scores for developing personal relationships with peers ( $M = 4.33$   $SD = 0.617$ ) and asking other students questions ( $M = 4.27$ ,  $SD = 0.704$ ), demonstrating improved collaboration. Qualitatively, students expressed overwhelmingly positive emotional responses, describing the experience as "fun" and "exciting," and perceived notable educational benefits, such as improved computer skills and more interactive learning. However, the research also acknowledges the existence of technical barriers, particularly concerning the clarity of error messages and system feedback, which received the lowest mean score ( $M = 2.93$   $SD = 0.961$ ). This study emphasizes how modern metaverse technologies can facilitate educational processes by making them more interesting and engaging. The outcomes demonstrate that the integration of metaverse platforms like Spatial.io within integrated flipped classroom courses signifies a promising advancement in educational technology geared towards more personalized and collaborative learning.

**Keyword:** metaverse, flipped classroom, Spatial.io, immersive learning environment, Virtual Reality

## INTRODUCTION

The contemporary educational landscape is undergoing a profound digital transformation, catalyzing a paradigm shift from conventional pedagogical models toward innovative approaches that harness technology to optimize student engagement and learning outcomes (Joseph et al., 2024; Toktarova & Semenova, 2020; Zain, 2020). Among these transformative pedagogical innovations, the flipped classroom model has gained significant traction. This model inverts the traditional instructional structure by delivering foundational content, such as video lectures and readings, for students to engage with independently outside of formal class time. This strategic rearrangement liberates in-person sessions for more interactive, collaborative, and applied learning activities, thereby fostering active learning, facilitating personalized instruction, and potentially improving academic performance (Akçayır & Akçayır, 2018; Han, 2022).

Despite its documented potential, the effective implementation of the flipped classroom model encounters persistent challenges. A primary concern is cultivating deep student engagement with pre-class materials, as

insufficient engagement undermines the efficacy of subsequent in-class activities (Baig & Yadegaridehkordi, 2023). Furthermore, within in-class settings, stimulating genuine participation and maintaining attentiveness among all students, particularly those who are more introverted, remains a pedagogical hurdle. Traditional environments often struggle to transcend superficial engagement, such as passive note-taking, in favor of truly immersive and collaborative knowledge construction (Long et al., 2016; Swart & MacLeod, 2021). These challenges underscore an urgent need for more dynamic and captivating environments to facilitate the interactive phase of the flipped classroom.

The emergence of the metaverse, defined as a confluence of interconnected, immersive virtual worlds, presents a promising solution to these enduring educational challenges (Chen et al., 2024; Kaddoura & Husseiny, 2023; López-Belmonte et al., 2023). Enabled by advancements in virtual reality, augmented reality, and mixed reality, collectively known as extended reality technologies, the metaverse offers a robust platform for creating highly interactive and experiential learning environments (Allcoat et al., 2021; Huang & Tseng, 2025; Λαμπρόπουλος & Kinshuk, 2024). These environments transcend the physical and logistical limitations inherent in traditional classrooms, enhancing motivation and engagement through immersive experiences (Chen et al., 2023; Suhag, 2025). Within this burgeoning digital realm, platforms like Spatial.io are pioneering novel forms of virtual collaboration. Spatial.io functions as a web-based and VR-ready platform, enabling users to interact as avatars within customizable 3D virtual spaces. Its key educational features include the capacity to establish persistent virtual classrooms, facilitate real-time collaboration through interactive whiteboards and 3D model integration, and offer spatial audio that replicates natural conversational dynamics, alongside support for diverse media formats for engaging content presentation.

Integrating a platform such as Spatial.io into the flipped classroom model offers educators the potential to cultivate a more compelling and immersive environment for the in-class phase. The novel and gamified nature of a metaverse environment can intrinsically boost motivation for engagement with both pre-class and in-class materials (Pyae et al., 2023). Its inherent collaborative features are specifically designed to facilitate dynamic group work, discussion, and peer-to-peer learning, thereby directly addressing the collaboration and participation challenges often observed in traditional flipped settings.

While the existing body of literature on flipped classrooms is substantial, and research concerning the educational applications of the metaverse is expanding, a discernible empirical research gap persists regarding the integration of these two innovations. Specifically, there is a paucity of studies examining the practical integration of accessible metaverse platforms, such as Spatial.io, within a structured flipped classroom pedagogy. Moreover, much of the extant research predominantly focuses on higher education contexts, leaving its application in secondary school settings notably underexplored. This study, therefore, aims to bridge this identified gap by investigating the following research question: How does the integration of the Spatial.io metaverse platform impact student engagement specifically in terms of participation, attentiveness, and collaboration within a flipped classroom model for secondary school students? This paper will present findings from an exploratory action research study conducted with a Form 2 Computer Science class, contributing empirical evidence on the potential and pitfalls of metaverse-enabled flipped learning.

## LITERATURE REVIEW

### Theoretical Foundations of the Flipped Classroom

The flipped classroom model transcends a mere reordering of instructional sequences; it is a pedagogical approach deeply rooted in constructivist learning theory (N, 2024). This theory posits that learners actively construct knowledge through experience and reflection, moving beyond passive reception of information (Schell & Janicki, 2013). The flipped model operationalizes this by shifting content delivery to an individual, pre-class space, thereby transforming collective classroom time into a dynamic workshop for active, social knowledge construction (Birgili et al., 2021; Robertson, 2022; Shahana. & -, 2024). This approach fosters independence in

knowledge acquisition and facilitates deeper understanding through interactive engagement (Kanjug et al., 2018; Utami et al., 2021).

A pivotal framework for understanding this model is derived from Strayer's foundational research on the flipped classroom (Strayer, 2012). Strayer emphasized that the success of the flip fundamentally hinges on the activities conducted during the in-class phase. He found that this time must be purposefully dedicated to higher-order cognitive activities, such as analysis, evaluation, and creation, facilitated through collaborative problem-solving and peer interaction (Hu, 2022; Lee & Lai, 2017; Long et al., 2016). Within this framework, the teacher's role evolves from a "sage on the stage" to a "guide on the side," providing personalized support and fostering a vibrant community of learners (Sofya et al., 2020). This study is built upon this framework, positing that the in-class phase serves as the critical lever for enhancing engagement and promoting deep learning.

Furthermore, the integration of advanced technologies, such as the metaverse, into this model can be conceptualized through Christensen's theory of disruptive innovation. Disruptive innovations typically enter a market by addressing overlooked segments with simpler, more accessible, or more convenient alternatives before gradually displacing established competitors (Manocha et al., 2022). Metaverse platforms like Spatial.io represent a potential disruptive force in education because they do not merely digitize traditional lectures, but rather offer a fundamentally new paradigm for collaboration and interaction (Joshi & Pramod, 2023). By initially catering to niche, innovative applications, these platforms hold the potential to disrupt traditional and even conventional flipped classroom models by offering a more engaging, immersive, and equitable environment for the active learning advocated by Strayer.

### **The Metaverse and Immersive Technologies in Education**

The educational potential of immersive virtual environments is extensively documented. Research into Virtual Reality and Augmented Reality collectively often referred to as Extended Reality technologies has consistently shown that these tools can significantly increase student motivation, engagement, and knowledge retention (Castro & Garduño, 2024). This is achieved by providing experiential learning opportunities that may be otherwise impossible, dangerous, or cost-prohibitive in the physical world (Bermejo et al., 2023; Shankar, 2023). Studies have demonstrated benefits such as improved spatial understanding of complex concepts through 3D graphics (Maraza-Quispe et al., 2021; Özçakır & Çakıroğlu, 2021; Pastor et al., 2023), enhanced simulation-based training, and a greater sense of "presence" that fosters a deeper connection to the learning material (Natale et al., 2020). Collaborative multi-user augmented reality solutions also show promise in fostering interaction between teachers and students (Masneri et al., 2022).

Platforms such as Spatial.io, AltspaceVR, and similar offerings represent the evolution of these technologies into cohesive social metaverse spaces (Duan et al., 2021; Jovanović & Milosavljević, 2022). These platforms move beyond isolated VR experiences to create persistent virtual worlds where the primary value extends beyond mere immersion to encompass robust collaboration (Alpala et al., 2022; Schaf et al., 2012). Features such as spatial audio, avatar-based interaction, and shared digital objects are specifically designed to facilitate natural communication and teamwork (Berndt et al., 2023; Hu et al., 2023; Rante et al., 2023), directly aligning with the social-constructivist requirements inherent in Strayer's flipped classroom model.

### **Theoretical Frameworks for Measuring Engagement and Collaboration in Digital Environments**

Measuring student engagement in technology-mediated learning environments is a critical but complex endeavor, with inconsistencies noted in definitions and measurement scales across studies (Henrie et al., 2015). Various approaches and frameworks have been proposed to quantify and understand student involvement in digital spaces. For instance, data-driven methodologies utilize the systematic analysis of digital interactions and events during synchronous virtual lessons to measure engagement (Solé-Beteta et al., 2022). Other models emphasize multi-dimensional perspectives, categorizing engagement into behavioral, cognitive, social, and emotional dimensions within online contexts (Ayouni et al., 2021). Further research explores real-time measurement of student

engagement through behavioral analysis, including facial expressions, keyboard activity, and mouse movements (Altuwairqi et al., 2021). These frameworks provide a foundation for understanding and assessing student involvement in virtual learning, emphasizing the importance of active participation, cognitive presence, and social interaction for effective learning outcomes.

## Identifying the Research Gap

Despite the robust theoretical alignment and promising empirical evidence from related fields, a critical gap persists in the literature. While numerous studies extol the potential of the metaverse in education, and a vast body of research supports the flipped classroom model, there remains a striking lack of empirical investigations into their integrated application (López-Belmonte et al., 2023). Systematic reviews of the metaverse in education generally acknowledge that research is still in its infancy across all educational levels, and more comprehensive studies are needed to assess its impact and improve its effectiveness (López-Belmonte et al., 2023). Most existing research tends to exist in silos:

- Studies on the metaverse frequently focus on its technological features or its use for single virtual lectures or field trips, rather than as a sustained environment for a structured pedagogical model like the flipped classroom (Lin et al., 2022; Zhang et al., 2022). Research specifically on the metaverse in secondary education as a pedagogical model, rather than for specific skill development, remains limited.
- Conversely, studies on the flipped classroom typically utilize conventional technologies, such as video lectures and Learning Management Systems for the pre-class phase, and traditional group discussions for the in-class phase (Allasasmeh, 2021; Mesa et al., 2022; Yano, 2022).

Furthermore, the application of these integrated models in secondary education is particularly underexplored (George-Reyes, 2020), with most research predominantly focused on university or professional training contexts (Batalla & Pedrero, 2023; Panuntun & Sipayung, 2023). Crucially, direct academic research on specific, accessible metaverse platforms like Spatial.io in an educational context, particularly within a flipped classroom model, is notably scarce. The specific question of how such a platform can tangibly impact measurable dimensions of student engagement specifically participation, attentiveness, and collaboration within the defined structure of a flipped classroom for secondary school students remains largely unanswered (Flores-Castañeda et al., 2024; Kaddoura & Hussein, 2023; Maghaydah et al., 2024).

This study aims to bridge this critical gap. It does not seek to merely implement a new technology, but rather to investigate a theoretically grounded pedagogical innovation: using the metaverse not as a novelty, but as the designated environment for the active, collaborative, in-class phase of the flipped model. By applying Christensen's lens, it treats Spatial.io as a disruptive tool and, through an action research approach, evaluates its efficacy in enhancing the student engagement that Strayer identified as crucial, thereby contributing practical insights to the future of hybrid learning models.

## METHODOLOGY

### Research Design and Participants

This study employed an exploratory action research design to investigate the integration of the Spatial.io metaverse platform into an adapted flipped classroom model. Action research was deemed appropriate as it allows for iterative cycles of planning, acting, observing, and reflecting within a real-world educational setting, facilitating a deep understanding of practical implementation and its effects.

The participants consisted of a purposive sample of 15 students (9 female, 6 male) from a Form 2 class (equivalent to 8th grade, aged 14) at a secondary school in Malaysia. All participants were enrolled in a compulsory Basic Computer Science course. This sample size was selected to facilitate a rich, in-depth qualitative and quantitative analysis within the manageable scope of an initial exploratory study, focusing on the depth of engagement rather

than statistical generalizability. The sample was selected to include a mix of high, medium, and low academic achievers with varying prior exposure to virtual reality tools.

To ensure participants possessed the necessary baseline skills, students from the Form 2 class were selected as they were concurrently studying Basic Computer Science. The virtual environment was designed using Spatial.io to meet minimal technological requirements, and relevant activities were developed to align with their curriculum.

### Data Collection and Instruments

A mixed-methods approach was used to triangulate data and provide a comprehensive understanding of student engagement.

1. **Quantitative Data:** A survey was administered post-intervention. The instrument was adapted from the validated ECAR Student Technology Survey, featuring Likert-scale items (1=Strongly Disagree to 5=Strongly Agree) designed to measure three core dimensions of engagement: participation rates, attentiveness, and collaboration.
2. **Qualitative Data:** To gain nuanced insights into the student experience, semi-structured interviews and open-ended questionnaires were conducted. These were designed to elicit student perceptions of the platform's usability, its impact on their learning, and the challenges they faced.
3. **Platform Analytics:** Interaction metrics within the Spatial.io environment, such as time-on-task and frequency of participation in activities, were passively collected to provide objective behavioural data to complement the self-reported survey and interview responses.

### Procedure

This study adapted the traditional flipped classroom model. Recognizing that student familiarity with the Spatial.io platform was a prerequisite for collaboration, the standard 'pre-class' phase of independent content acquisition was replaced with a structured, guided in-metaverse session. The intervention was conducted over two dedicated sessions (120 minutes each):

- **Session 1 (Guided Exploration and Skill Acquisition):** This session served as the adapted 'pre-class' phase, conducted in the metaverse. Students were introduced to the Spatial.io platform. Following a short tutorial, they were divided into small groups and assigned a virtual space to freely explore the platform's core functionalities with instructor guidance. Subsequently, each group was assigned a collaborative task related to their Computer Science curriculum (e.g., designing a flowchart for a simple algorithm within the virtual space).
- **Session 2 (Application and Data Collection):** This session represented the core 'in-class' phase of the flipped model, focusing on applied, collaborative project work and assessment. Student groups reconvened in Spatial.io to present and demonstrate their completed tasks. Following the presentations, all quantitative surveys and qualitative interviews were administered to capture their experiences and perceptions immediately after the intervention.

This two-stage procedure operationalized the flipped classroom model by shifting initial exploration and skill acquisition (Session 1) to a guided, in-virtual-class activity, while using the second session for higher-order applied collaboration and assessment.

## RESULT

### Demographic of Participants

Participants for this study are students in Form 2 that taking Basic Computer Science (Asas Sains Komputer) as their elective. The demographic of the students as per tabulated below:

Table 1: Participant by Gender

| Gender | No. |
|--------|-----|
| Female | 9   |
| Male   | 6   |
| Total  | 15  |

There are 15 students from Form 2 that are taking this elective, consist of 9 female students (60%) and 6 male students (40%). While larger sample sizes typically offer more reliable results, a sample of 15 students can still provide valuable insights, especially in the context of an initial action research or pilot study for new technology such as using Spatial.io in flipped classroom. However, the findings may not be easily generalizable to a broader population. Additionally, the gender distribution in this sample, with 9 female and 6 male participants, is relatively balanced, which helps in minimizing gender bias and allows for the exploration of potential differences in engagement between male and female students

For this study, I will ensure that students possess the necessary basic computer skills and knowledge. Therefore, I have chosen 15 students from the form 2 class, as they are currently studying Basic Computer Science. Additionally, I will design the virtual environment using Spatial.io to meet minimal technological requirements. I will also develop relevant activities, identify potential challenges, and prepare appropriate solutions to address them.

### User Experience with Spatial.io

Overall, students reported a favourable experience using the Spatial.io platform for learning. As shown in Table 2, participants found the system easy to use ( $M=4.13$ ,  $SD=0.640$ ), were satisfied with its overall functionality ( $M=4.13$ ,  $SD=0.743$ ), and were able to complete their assigned tasks effectively ( $M=4.13$ ,  $SD=0.640$ ). The interface was perceived as pleasant ( $M=3.73$ ,  $SD=0.704$ ) and easy to navigate. However, the results also indicate notable areas for improvement, particularly in the clarity of error messages and system feedback ( $M=2.93$ ,  $SD=0.961$ ), which was the lowest-scoring aspect of the user experience.

Table 2: User Experience with the Spatial.io Platform

| No. | Item                                                       | Mean | Std. Deviation |
|-----|------------------------------------------------------------|------|----------------|
| 1.  | It was simple to use the system.                           | 4.13 | 0.640          |
| 2.  | I was able to complete the tasks using this system.        | 4.13 | 0.640          |
| 3.  | Overall, I am satisfied with this system.                  | 4.13 | 0.743          |
| 4.  | I felt comfortable using this system.                      | 3.87 | 0.640          |
| 5.  | The interface of this system was pleasant.                 | 3.73 | 0.704          |
| 6.  | The system gave error messages to clearly fix the problem. | 2.93 | 0.961          |

### Technology's Role in Student Engagement

The integration of Spatial.io was perceived by students to have significantly enhanced key dimensions of their engagement. Table 3 shows that the technology was most effective in facilitating social and collaborative learning. The highest mean scores were reported for developing personal relationships with peers ( $M=4.33$ ), asking other students questions ( $M=4.27$ ), and understanding teachers' expectations ( $M=4.27$ ). The platform was also highly effective for documenting classwork ( $M=4.40$ ) and conducting research for assignments ( $M=4.13$ ).

Table 3: Perceived Impact of Technology on Engagement

| No. | Item                                                                      | Mean | Std. Deviation |
|-----|---------------------------------------------------------------------------|------|----------------|
| 1.  | Technology helped me document class works or projects.                    | 4.40 | 0.507          |
| 2.  | Technology helped me develop a personal relationship with other students. | 4.33 | 0.617          |
| 3.  | Technology helped me ask other students questions.                        | 4.27 | 0.704          |
| 4.  | Technology helped me understand my teachers' expectations.                | 4.27 | 0.458          |
| 5.  | Technology helped me conduct research for class assignments.              | 4.13 | 0.640          |
| 6.  | Technology helped me learn through games or interactive activities.       | 4.13 | 0.352          |
| 7.  | Technology helped me participate in group activities.                     | 3.53 | 0.915          |

### Thematic Analysis of Qualitative Findings

A thematic analysis of qualitative data from survey responses was conducted to identify common patterns in student perceptions. Four primary themes emerged, as summarized in **Table 4**.

**Theme 1: Positive Emotional Response.** Students overwhelmingly expressed positive initial reactions to the metaverse classroom. Feelings were frequently described using words like "happy," "fun," "exciting," and "interesting." For instance, some students said, "I feel happy," and "It was very fun and exciting."

**Theme 2: Perceived Educational Benefits.** Students identified several advantages, emphasizing improvements in computer skills and increased engagement due to interactive elements. Representative comments included, "Metaverse classroom helps me improve my computer skills," and "It makes learning more fun and interactive."

**Theme 3: Comparison of Learning Environments.** Perspectives on metaverse versus conventional classrooms were diverse. A notable portion of students preferred the metaverse, citing its engaging nature example "Metaverse classroom is more fun and engaging"). Others acknowledged the value of traditional settings for maintaining focus such as "Conventional classroom helps students focus more".

**Theme 4: Willingness to Recommend.** Most students indicated a strong willingness to recommend Spatial.io to peers and other teachers, underscoring their positive experience. Examples include: "Yes, because Spatial.io is very easy to use and engaging," and "Yes, I will suggest my friend to use Spatial.io."

Table 4: Thematic Analysis of Student Perceptions

| Theme                          | Description                                                                                         | Representative Quote                                                                                   |
|--------------------------------|-----------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|
| Positive Emotional Response    | Initial feelings of enjoyment and excitement toward the new learning environment.                   | "I feel happy."<br>"It was very fun and exciting."                                                     |
| Perceived Educational Benefits | Belief that the platform improved technical skills and made learning more interactive.              | "It helps me improve my computer skills."<br>"It makes learning more fun and interactive."             |
| Comparison of Environments     | Divided preference between the engagement of the metaverse and the focus of traditional classrooms. | "Metaverse classroom is more fun and engaging."<br>"Conventional classroom helps students focus more." |
| Willingness to Recommend       | A strong advocacy for adopting the platform based on a positive user experience.                    | "Yes, because Spatial.io is very easy to use and engaging."                                            |

## DISCUSSION

This exploratory action research study investigated the impact of integrating the Spatial.io metaverse platform on student engagement, specifically participation, attentiveness, and collaboration, within an adapted flipped classroom model for secondary school students. The findings indicate that the platform successfully enhanced these key dimensions of engagement, thereby addressing persistent challenges often encountered in traditional flipped classroom implementations, particularly in fostering deeper interaction during in-class phases.

The quantitative results from the student survey clearly demonstrate Spatial.io's effectiveness in facilitating social and collaborative learning. As presented in Table 3, students reported high mean scores for developing personal relationships with peers ( $M=4.33$ ,  $SD= 0.617$ ), asking other students questions ( $M=4.27$ ,  $SD= 0.704$ ), and understanding teachers' expectations ( $M=4.27$ ,  $SD= 0.458$ ). These findings strongly align with Strayer's foundational framework of the flipped classroom, which posits that the in-class phase is paramount for higher-order cognitive activities, collaborative problem-solving, and peer interaction (Long et al., 2016; Strayer, 2012). The metaverse environment, therefore, successfully transformed the virtual classroom into a dynamic workshop for active, social knowledge construction, where the teacher's role evolved from a didactic "sage on the stage" to a facilitative "guide on the side," consistent with constructivist pedagogical principles (Sofya et al., 2020). Furthermore, the platform's disruptive potential, as conceptualized by Christensen's theory of disruptive innovation, was evident (Manocha et al., 2022). Spatial.io did not merely digitize a traditional lecture but offered a fundamentally new paradigm for interaction a persistent, immersive 3D space that fostered a sense of presence and natural collaboration, transcending the limitations of conventional video conferencing or learning management systems ( Joshi & Pramod, 2023).

The qualitative findings, derived from thematic analysis, further corroborate and enrich these quantitative observations. As summarized in Table 4, the overwhelmingly positive emotional responses, characterized by descriptions like "happy," "fun," and "exciting," underscore the intrinsic motivation generated by the novel learning environment. This aligns with existing literature on immersive technologies (VR/AR) in education, which consistently highlights increased student motivation and engagement through experiential learning (Castro & Garduño, 2024; Chen et al., 2023). Students also perceived significant educational benefits, particularly in improving computer skills and finding learning more interactive, reinforcing the platform's utility as a tool for practical skill development and enhanced pedagogical delivery. While the mean scores for user experience generally indicated high satisfaction, particularly regarding ease of use ( $M=4.13$ ,  $SD= 0.64$ ) and task completion ( $M= 4.13$ ,  $SD= 0.640$ ), the thematic analysis also revealed a nuanced perspective. Students expressed a divided preference, acknowledging the metaverse's engagement while recognizing the comparative strength of traditional classrooms for maintaining focus. This suggests that a hybrid approach, strategically leveraging the unique strengths of both immersive virtual environments and physical settings, may represent the most effective future strategy for educational models. Prior research also points to user experience and usability being critical factors for effective metaverse learning environments (Pyae et al., 2023).

Despite these promising findings, several limitations of this exploratory study must be acknowledged. The relatively small sample size of 15 students inherently limits the statistical power and generalizability of the quantitative findings to a broader population. Furthermore, the short duration of the intervention raises the possibility that the observed enhancements in engagement might, in part, be attributable to a "novelty effect" rather than a sustained long-term impact of the metaverse environment (Chua & Yu, 2023). Crucially, the quantitative data on user experience also highlighted a significant technical barrier: the lowest mean score was recorded for the clarity of error messages and system feedback ( $M= 2.93$ ,  $SD = 0.961$ ). This issue underscores a critical challenge for equitable and seamless implementation, as technical glitches can disrupt flow and diminish engagement, particularly for students with varying levels of digital literacy or access to robust hardware. Such technical and accessibility challenges are well-documented in the broader literature on technology adoption, including in AI implementation within industries (Ivchyk, 2024; Kamrozzaman et al., 2025; Rasdi & Baki, 2025) and among higher education students using AI tools (Du et al., 2025; Jie & Kamrozzaman, 2024; Lin & Qiu, 2024; Sousa & Cardoso, 2025). This broader context suggests that overcoming technical friction is a common hurdle for integrating novel technologies into diverse environments.

Future research should therefore address these limitations by conducting longer-term longitudinal studies with larger, more diverse cohorts of secondary school students to validate these preliminary findings and assess the sustained impact of metaverse-flipped learning over a full academic term. Investigations could also benefit from directly comparing learning outcomes between metaverse-flipped and traditional flipped classroom models to empirically quantify the pedagogical advantages. Moreover, future studies should focus on developing best practices for curriculum design, technical support, and troubleshooting within these immersive platforms to mitigate accessibility issues and optimize the learning experience. Despite its limitations, this exploratory study provides valuable empirical evidence for the potential of metaverse platforms like Spatial.io to disrupt and enhance the flipped classroom model. It moves beyond theoretical speculation to offer practical insights into the implementation, benefits, and pitfalls of creating more engaging, collaborative, and immersive virtual learning environments in secondary education.

## LIMITATIONS AND FUTURE RESEARCH

This study provides initial evidence for the potential of metaverse platforms in education; however, several limitations must be acknowledged, which correspondingly delineate pathways for future inquiry.

A significant methodological limitation is the absence of a control group or a comparative baseline from a traditional flipped classroom setting. This design precludes definitive causal inferences regarding the unique impact of the Spatial.io platform, as the observed enhancements in engagement may be attributable to extraneous variables or the novelty of the intervention itself.

Furthermore, the study's focus on immediate, short-term engagement outcomes offers no insight into long-term effects. The sustainability of engagement, its correlation with knowledge retention, and its ultimate influence on academic performance remain unexamined. Additionally, the investigation did not explore the potential cognitive load implications of navigating immersive virtual environments, which could influence learning efficiency over prolonged use.

To address these constraints and build upon the present findings, the following research directions are proposed:

1. **Longitudinal Studies:** Future research should implement longitudinal designs to assess the sustainability of engagement and its effects on knowledge retention and academic achievement over an extended period, such as a full academic semester.
2. **Comparative Experimental Designs:** Employing quasi-experimental designs with control groups would allow researchers to empirically isolate the impact of the metaverse environment by comparing it directly with traditional or other technology-mediated flipped classroom models.
3. **Diversification of Contexts:** Investigating the model across a wider range of academic subjects and educational settings is necessary to determine the generalizability of the findings beyond the context of secondary school computer science education.
4. **Cognitive Load Assessment:** Subsequent studies should explicitly measure the cognitive load imposed by metaverse platforms to ensure that the immersive experience facilitates, rather than impedes, the cognitive processes essential for deep learning.

Pursuing these avenues will contribute to a more comprehensive and nuanced understanding of how metaverse technologies can be effectively integrated into pedagogical frameworks to support sustained and meaningful educational outcomes.

## CONCLUSION

The integration of Spatial.io into a metaverse flipped classroom model holds significant potential for transforming modern education. This study highlights how the platform enhances student engagement, attentiveness, and collaboration, reinforcing established educational theories such as Strayer's flipped classroom model and Christensen's disruptive innovation theory. While the findings demonstrate promising outcomes, challenges such

as technical barriers, privacy concerns, and equitable access must be carefully navigated. To fully harness the benefits of this innovative approach, educators and policymakers should embrace hybrid learning models, invest in targeted training, and implement strong privacy safeguards. Moving forward, continuous refinement and thoughtful implementation will be essential to unlocking the full educational potential of metaverse technologies.

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