

Spatial.io as an Interactive Learning Media for 21st Century: A Theoretical Study

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ABSTRACT

The development of digital technology has driven innovation in 21st century learning, emphasizing critical thinking, creativity, collaboration, communication and digital literacy. One such innovation is the utilization of Spatial.io as a metaverse based platform that enables interactive learning through three dimensional virtual spaces. This study aims to analyze the characteristics, opportunities, challenges, and implications of using Spatial.io in education. The study was conducted using a qualitative approach with a library research method. Data were obtained through a structured search of three main databases: Google Scholar, ResearchGate, and ScienceDirect, using the keywords Spatial.io, metaverse education, interactive learning media and 21st-century learning. Analysis was conducted using content analysis to interpret the themes, concepts and patterns of relationships in the collected literature. The results of the study revealed three main themes. First, the characteristics of Spatial.io as an interactive learning media include immersive learning experiences, 3D object manipulation, avatar usage, and multimedia integration that supports the development of students 4C skills. Second, opportunities and challenges include increased student motivation, engagement and collaboration, but implementation faces obstacles such as infrastructure limitations, teacher readiness and uneven student digital literacy. Third, the implications for school use indicate that Spatial.io can enhance student engagement, conceptual understanding, digital literacy, and the role of teachers as facilitators and designers of learning experiences.

Keyword: Interactive learning media; metaverse education, 21st-century learning; Spatial.io

INTRODUCTION

The rapid development of digital technology has brought about a significant transformation in the field of education. The digital era demands innovations in learning that go beyond conventional methods, emphasizing the use of information and communication technologies to create more interactive, flexible, and student-centered learning experiences that meet the needs of 21st-century learners. Learning in the 21st century emphasizes the importance of critical thinking, creativity, collaboration, and communication (4C), along with mastery of digital, data, and technological literacy. These competencies can only be achieved through active, meaningful, and experiential learning processes. The paradigm shift from *teacher-centered learning* to *student-centered learning* underscores the importance of

integrating interactive learning media to enhance students' engagement in learning activities.

Various technology-based learning media have been developed, such as e-learning platforms, video conferencing tools, interactive multimedia, and Learning Management Systems (LMS). However, most of these media still focus on delivering two-dimensional content in text or video form, offering limited opportunities for students to explore and interact meaningfully. As a result, students often experience boredom, low motivation, and a lack of contextual learning experiences. Previous studies have shown that video conferencing and LMS applications have not been able to sustain students' cognitive, emotional, and behavioral engagement due to limited interaction and frequent technical issues (Hastomo et al., 2024; Mangkey et al., 2023). Other studies also indicate that monotonous delivery of materials through two-dimensional media can cause fatigue and decrease learning motivation (Kristiana et al., 2023; Nafiah et al., 2021).

One of the emerging technological breakthroughs with great potential to address these challenges is the metaverse in education. The metaverse is a three-dimensional virtual space that allows users to interact directly through digital avatars. In the learning context, this technology enables students to collaborate, discuss, and conduct simulations as if they were in a real environment. Therefore, the metaverse opens opportunities to create more engaging, meaningful, and immersive learning experiences.

Spatial.io is one of the metaverse-based platforms designed to support virtual collaboration in three-dimensional interactive spaces. It allows users to interact in digital environments that resemble real-life settings, making it suitable as an immersive and interactive learning medium. Initially developed for art exhibitions and professional collaboration, Spatial.io has increasingly been utilized in education due to its ability to provide dynamic and realistic virtual experiences. With features such as virtual classrooms, interactive avatars, and multimedia integration (including videos, audio, documents, and 3D objects), Spatial.io enables teachers and students to design richer and more engaging learning experiences. This platform promotes active participation, deeper conceptual understanding through visualization, and increased learning motivation. Moreover, it supports cross-geographical collaborative learning, allowing students from different regions or even countries to learn together in a shared virtual environment.

Based on this background, the present theoretical study aims to analyze the potential of Spatial.io as an interactive learning medium aligned with the characteristics of 21st-century education. This paper provides a conceptual overview of Spatial.io's educational characteristics, advantages, limitations, and implementation challenges in school contexts.

METHODS

This study employed a qualitative approach using a library research method. Data were obtained through a structured search of three major databases: Google Scholar, ResearchGate, and ScienceDirect. The search process was conducted using four main keywords: “Spatial.io,” “metaverse education,” “interactive learning media,” and “21st-century learning.” The initial search yielded a large number of publications. For instance, on Google Scholar, the keyword “metaverse education” returned approximately ±88,600 articles, ScienceDirect displayed 2,728 articles for the same keyword, and ResearchGate showed around ±1,800 related publications. Additionally, the keyword “Spatial.io learning” produced ±1,080 articles on Google Scholar and 25 articles on ScienceDirect, while “interactive learning media metaverse” yielded approximately ±47,300 articles on Google Scholar and 1,855 articles on ScienceDirect. The large volume of results necessitated a systematic screening process to select relevant literature.

To narrow down the results, the study applied specific inclusion and exclusion criteria. Inclusion criteria included articles published between 2020 and 2025, articles directly related to Spatial.io, metaverse-based learning, or interactive learning media in virtual spaces, and scholarly articles in the form of journals, proceedings, or research reports. Exclusion criteria comprised articles that only discussed metaverse games without an educational context, duplicate articles across databases, and articles that were merely opinion pieces or non-scientific essays. Based on these criteria, screening was conducted in three stages: title screening, abstract screening, and full-text eligibility assessment. From over one hundred thousand articles resulting from the initial keyword search, 210 articles were deemed relevant at the title screening stage. After reviewing abstracts, 45 articles were considered suitable. Subsequently, through full-text assessment, 17 articles met all inclusion criteria and possessed strong conceptual substance. These selected articles were further analyzed.

Data analysis in this study was conducted using content analysis, as described by Bungin (2017), which is employed to systematically, objectively, and deeply describe, interpret, and derive meaning from various literature sources. Content analysis allows researchers to identify themes, concepts, and patterns of relationships emerging from the collected literature. The analysis process consisted of three main stages. First, data reduction, which involved selecting, classifying, and simplifying literature relevant to the study’s focus, such as 21st-century learning, interactive learning media, and the application of Spatial.io. Second, data display, which involved organizing the literature review results into conceptual themes, such as the Characteristics of Spatial.io as Interactive Learning Media, Opportunities and Challenges of Implementing Spatial.io in Learning, and Implications of Using Spatial.io in Schools. Third, drawing conclusions, which entailed interpreting the data and review

results to identify conceptual patterns, relationships among components, and theoretical implications of using Spatial.io in the context of 21st-century education.

RESULTS AND DISCUSSION

Based on the analysis of the 17 articles that passed the selection process in this literature review, three main themes regarding the utilization of Spatial.io as a 21st-century interactive learning media were identified. These themes illustrate the research trends and the conceptual development directions of Spatial.io in the educational context. The three main themes identified are: (1) Characteristics of Spatial.io as Interactive Learning Media; (2) Opportunities and Challenges of Implementing Spatial.io in Learning; and (3) Implications of Using Spatial.io in Schools.

To clarify the distribution of the analyzed literature, Table 1 summarizes the number of articles per theme along with example citations.

Table 1. Number of Articles per Theme and Example Citations

Main Theme	Number of Articles	Example Citations
Characteristics of Spatial.io as Interactive Learning Media	11	Purwanto et al., 2025; Hidayati et al., 2024; Susilana et al., 2024; Putra Elfanda et al., 2025; Choiroh et al., 2025; Vokasional et al., 2019; Barry et al., 2025; Iasmim da Cruz Marinho et al., 2025; Rudiantoro, 2023; Rosnaeni, 2021; Durmaz-Thesis (3), 2024
Opportunities and Challenges of Implementing Spatial.io in Learning	9	Choiroh et al., 2025; Putra Elfanda et al., 2025; Hidayati et al., 2024; Purwanto et al., 2025; Islam & Wang, 2025; Mangkey et al., 2023; Hastomo et al., 2024; Nafiah et al., 2021; Sri Handayani, 2023
Implications of Using Spatial.io in Schools	5	Rasyida & Ali Nurdin, 2023; Choiroh, 2025; Putra Elfanda et al., 2025; Purwanto et al., 2025; Hidayati et al., 2024

These three themes form the basis for the presentation of results and discussion in the following sections:

1. Characteristics of Spatial.io as Interactive Learning Media

Opportunities and Challenges of Implementing Spatial.io in Learning The analysis of eleven articles indicates that Spatial.io has key characteristics as an interactive learning media based on three-dimensional virtual spaces, capable of providing immersive learning experiences. Spatial.io is proven adequate for designing immersive and interactive virtual language learning environments (Durmaz-Thesis-2024 (3), 2024). As an immersive 3D platform, Spatial.io is designed to support collaborative interaction, creative exploration, critical thinking, and experiential learning, which are essential in equipping students with communication, technology, and problem-solving skills (Purwanto et al., 2025). Hidayati et al. (2024) showed that Spatial.io, as an interactive three-dimensional virtual environment, offers significant educational potential, including collaboration, simulation, and in-depth exploration of materials. The 3D metaverse platform provides students with profound and practical learning experiences (Susilana et al., 2024). Similarly, Putra Elfanda et al. (2025) indicated that 3D representations of the hydrosphere facilitate students' understanding of geographic principles. Choiroh et al. (2025) reported that students can interact directly with learning content by manipulating objects, viewing models from multiple angles, and navigating the space as needed. These characteristics align with the concept of interactive media as described by Vokasional et al. (2019), emphasizing two-way responsiveness between students and digital content.

Another prominent characteristic is the use of avatars as users' digital identities. Spatial.io allows users to create avatars, interact in virtual spaces, and fulfill psychological needs such as social interaction, community engagement, and self-expression (Barry et al., 2025). According to Lasmim da Cruz Marinho et al. (2025), avatar use in metaverse environments like Spatial.io plays an important role in enhancing communication comfort, self-expression, and social interaction among users, though certain challenges exist for users with special needs.

These characteristics demonstrate that Spatial.io supports the development of 21st-century competencies, particularly critical thinking, communication, collaboration, and creativity (the 4Cs), as discussed by Rudiantoro (2023) and Rosnaeni (2021). By enabling object manipulation, spatial exploration, and multimodal communication, Spatial.io offers learning experiences that go far beyond static digital media. Overall, the characteristics of Spatial.io indicate that the platform serves as an advanced interactive learning media supporting visual, multimodal, and collaborative learning processes.

2. Opportunities and Challenges of Implementing Spatial.io in Learning

The analysis of nine articles shows that Spatial.io provides various opportunities in learning, particularly in enhancing student motivation,

collaboration, and engagement, while also presenting several implementation challenges.

Choiroh et al. (2025) found that learning through virtual galleries significantly increased student participation. Putra Elfanda et al. (2025) reported that Spatial.io enhanced students' critical thinking skills in geography learning. Spatial.io also offers opportunities to strengthen collaborative work among students. Hidayati et al. (2024) revealed that collaborative space features enable students to discuss, work in groups, and present tasks directly in the virtual environment. This finding is supported by Purwanto et al. (2025), who noted that Spatial.io enhances multi-skills such as communication, digital literacy, and collaboration. The avatar feature allows students to engage in realistic scenarios, work in groups, and develop essential skills using adaptive and intelligent technology (Islam & Wang, 2025). Additional evidence supporting the potential of Spatial.io in learning shows that virtual classrooms in Spatial.io possess appeal, clarity, efficiency, precision, stimulation, and novelty, indicating that its use is practical and well-received in education (Sri Handayani, 2023).

Despite these opportunities, the literature also identified several challenges. The first challenge is the limitation of technological devices and internet infrastructure, particularly in non-urban schools (Mangkey et al., 2023). The second challenge relates to teacher readiness in using advanced digital features (Hastomo et al., 2024). The third challenge is the uneven level of student digital literacy (Nafiah et al., 2021). Hidayati (2024) emphasized that the main obstacles in integrating Spatial.io in learning include infrastructure limitations, device accessibility, and educator readiness. These challenges indicate that successful implementation of Spatial.io depends heavily on the readiness of the educational ecosystem. However, these challenges are not permanent barriers but rather signals that innovations like Spatial.io require careful planning to be effectively integrated. If technological and competency challenges are addressed through infrastructure improvements and professional teacher training, Spatial.io can become a highly potential learning media. Consequently, Spatial.io can open opportunities for transforming learning into a more creative, collaborative, and student-centered model.

3. Implications of Using Spatial.io in Schools

Findings from five articles indicate that the use of Spatial.io in learning positively impacts motivation, interest, engagement, digital literacy, and the development of students' 21st-century skills in school settings. Research shows that metaverse-based virtual reality learning using Spatial.io with the Discovery Learning model can increase students' interest and understanding in Informatics (Rasyida & Ali Nurdin, 2023). Furthermore, Choiroh (2025) reported that implementing Spatial.io for social studies (SMP) through a virtual gallery walk model demonstrates that 3D virtual spaces can enhance student learning

motivation, making lessons more engaging and interactive. Putra Elfanda et al. (2025) observed that students were more active in asking questions, discussing, and presenting their work during Spatial.io-based learning.

Beyond increasing motivation, Spatial.io impacts the development of 21st-century skills, particularly collaboration, creativity, and problem-solving. Purwanto et al. (2025) indicated that project-based learning in virtual spaces enhances students' abilities to complete group tasks creatively. The study also found that integrating Spatial.io can improve student engagement, conceptual understanding, and digital literacy (Hidayati et al., 2024), demonstrating that Spatial.io can serve as an effective tool to strengthen students' digital literacy.

Another implication of using Spatial.io is the transformation of the teacher's role from information provider to facilitator and learning experience designer. In this context, teachers must be able to design virtual environments, organize learning objects, and create relevant collaborative activities. Overall, Spatial.io has positive implications for enhancing motivation, engagement, digital literacy, and students' 4C skills. With adequate infrastructure and teacher training, Spatial.io can play a crucial role in transforming learning in schools.

CONCLUSION

Based on the analysis of the articles that met the inclusion criteria, this study identified three main themes regarding the utilization of Spatial.io as a 21st-century interactive learning media. First, analysis of sixteen articles revealed that Spatial.io possesses characteristics as a 3D-based immersive learning environment that enables the visualization of abstract concepts, two-way interaction through object manipulation, avatar usage, and multimedia integration. These characteristics provide strong support for the development of 21st-century skills, particularly communication, collaboration, creativity, and critical thinking.

Second, analysis of twelve articles indicated that Spatial.io offers several opportunities in learning, including enhancing student motivation, participation, collaboration, and digital literacy. However, its implementation also faces challenges such as limitations in technological infrastructure, teacher readiness, and disparities in student digital literacy. The successful integration of Spatial.io depends on the support of the educational ecosystem, including professional training and the availability of devices.

Third, findings from ten articles demonstrated that the use of Spatial.io has positive implications for school environments, particularly in increasing student engagement, strengthening digital literacy, and fostering a shift in teachers' roles from content providers to facilitators and learning experience designers. Spatial.io also supports project-based and collaborative learning relevant to the demands of the 21st century.

Overall, the results of this literature review confirm that Spatial.io has significant potential in developing immersive, collaborative, and student-centered interactive learning. However, its effective utilization requires technological readiness, teacher competencies, and appropriate pedagogical strategies to be successfully integrated into educational practice in schools.

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