Exploring the Impact of Minecraft-Based Projects on STEM and SDG Integration in Education: A Case Study

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ABSTRACT

This study explores the potential of Minecraft as an educational tool to enhance student engagement and motivation in STEM subjects while integrating Sustainable Development Goals (SDGs). Despite the growing interest in game-based learning, there is limited research on its impact on primary students' learning outcomes and the challenges faced by educators. This qualitative study involved five primary students who participated in a Minecraft-based project to design future schools, aiming to assess their engagement, motivation, and understanding of SDGs. The main findings indicate that Minecraft significantly increased student engagement and motivation through active participation, collaborative learning, and creativity. Students also demonstrated a deeper understanding of global issues and SDGs, applying their knowledge in practical, real-world contexts. However, technical, pedagogical, and resource challenges were identified as significant barriers to successful implementation. Practically, the study suggests that educators should incorporate game-based learning tools like Minecraft to foster creativity, collaboration, and real-world problem-solving skills, while addressing the identified challenges through adequate training and resource allocation. Theoretically, the findings contribute to the STEM-PBL principles, situated learning theory, and social constructivism by supporting the effectiveness of engaging, hands-on projects, authentic learning contexts, and collaborative knowledge construction. Future research should explore strategies to overcome implementation challenges, investigate the long-term impact of Minecraft-based projects on students' academic performance and career choices in STEM fields, and examine the potential of other game-based learning tools in various educational settings. In conclusion, this study highlights the transformative potential of Minecraft in education, offering valuable insights for enhancing STEM education and global awareness.

Keywords: Minecraft, STEM Education, Sustainable Development Goals, Game-based Learning

INTRODUCTION

The integration of digital tools in education has revolutionized the way students learn and engage with complex concepts. Minecraft, a popular sandbox video game, has emerged as a powerful educational tool, offering immersive and interactive learning experiences [21]. Using Minecraft in education enhances student engagement and motivation through its interactive nature. It fosters creativity, critical thinking, and teamwork, making learning more enjoyable and effective [13]. Minecraft's real-world applications, particularly in STEM subjects, enable students to understand complex concepts and develop essential digital literacy skills [1]. The game is inclusive and adaptable, catering to diverse learning styles and abilities. Additionally, incorporating global themes like the Sustainable Development Goals (SDGs) broadens students' perspectives on global issues [16]. Thus, Minecraft is a valuable tool that transforms traditional education into a dynamic and impactful experience.

Despite the recognized benefits of digital tools in education, there is limited research on the specific impact of Minecraft on STEM learning and global awareness. This study aims to address this gap by investigating how a project-based learning approach using Minecraft can enhance students' understanding of STEM concepts and SDGs. The research aims to address the following question: (i) How does using Minecraft to build future

schools affect students' engagement and motivation in STEM subjects? (ii) What are the educational outcomes of integrating SDGs into a Minecraft-based project? (iii) What challenges and limitations do students face when participating in such projects? Accordingly, the objectives of this study are to evaluate the impact of Minecraft on STEM engagement, assess the integration of SDGs in student learning, and identify barriers to implementation. By clearly articulating these questions and objectives, this study provides a structured roadmap for readers, ensuring coherence and clarity throughout the research narrative. Besides, the significance of this study lies in that it highlights the potential of Minecraft to enhance student engagement and motivation. It suggests that Minecraft can foster critical 21st-century skills, creativity, collaboration, and problem-solving. The study also emphasizes the importance of integrating Sustainable Development Goals (SDGs) into the curriculum to promote global awareness and responsibility among students.

LITERATURE REVIEW

Minecraft in Education

Minecraft has been increasingly recognized as a valuable educational tool. Studies have shown that Minecraft can enhance student engagement, creativity, and collaboration. It provides a platform for immersive learning experiences, allowing students to explore complex concepts in a virtual environment. Studies have shown that the platform not only increases student motivation but also serves to bridge the gap between theoretical concepts and practical application [7][22]. Minecraft Education Edition offers ready-to-teach lessons and customizable content that align with curriculum standards, making it a versatile tool for teaching various subjects, including STEM. For example, Peykova and Garov [18] illustrated how Minecraft Education Edition can be leveraged to develop algorithmic thinking and digital literacy. Their study showed that by incorporating game-based elements into lesson plans, educators can address diverse curriculum areas, from history and chemistry to computer science and mathematics, while promoting creative problem-solving and critical thinking skills.

SDGs in Education

Integrating Sustainable Development Goals (SDGs) into education promotes global awareness and responsibility. SDG4, which aims to ensure inclusive and equitable quality education, emphasizes the transformative power of education in achieving sustainable development. By incorporating SDGs into the curriculum, educators can help students understand the importance of sustainability and inspire them to contribute to global challenges [3]. Hobbs and Behenna [9] stated that Minecraft-based projects provide a dynamic platform for educators to engage students with sustainable engineering and environmental challenges, making abstract sustainability concepts accessible through interactive learning. Similarly, Kersánszki et al. [12] demonstrated that integrating Minecraft in lessons, particularly projects that examine renewable energy and other sustainable practices, can effectively bridge the gap between theoretical knowledge and practical application, thereby reinforcing the central principles of the SDGs. Therefore, building future schools in Minecraft can explain how education can address SDGs, fostering a sense of purpose and engagement among students.

STEM Pedagogy Principles

STEM education focuses on integrating science, technology, engineering, and mathematics to foster critical thinking, problem-solving, and innovation. Key principles of STEM pedagogy include hands-on learning, real-world problem-solving, and interdisciplinary approaches [10][17]. Project-based learning (PBL) is a core component of STEM education, encouraging students to apply their knowledge to practical challenges [8]. Research indicates that STEM project-based interventions lead to measurable improvements in problem-solving performance and teamwork, which are indispensable in today's increasingly interdisciplinary work scenarios [5][11].

Theoretical Framework

In this study, we used the STEM-PBL principles [23], situated learning theory [14], and social constructivism [2] as the foundation of this study (see Figure 1). The STEM-PBL principles serve as the core of the theoretical

foundation to emphasize learning through engaging, hands-on projects that integrate science, technology, engineering, and mathematics. The Minecraft project, where students designed and built their vision of a future school, exemplifies this approach. It fosters critical thinking, creativity, and real-world problem-solving, which are essential components of STEM education. Surrounding the core is the social constructivism layer. This theory highlights the importance of social interactions and collaboration in the learning process.

Fig.1 The theoretical framework of this study

In this study, students worked together in groups, sharing ideas and constructing knowledge collectively. The collaborative nature of the Minecraft project allowed students to learn from each other, negotiate meanings, and build knowledge together, reinforcing the social constructivist principle that learning is a social process [2]. The outer layer represents situated learning theory. This theory suggests that learning occurs best in context and through participation in authentic activities. The Minecraft project provided a situated learning experience, where students engaged in meaningful tasks that resembled real-world challenges, such as designing sustainable schools. This approach helped students see the relevance of their learning and apply their knowledge in practical, authentic contexts, aligning with the situated learning principle that knowledge is best acquired in real-world settings.

Conceptual Framework

Building upon the theoretical foundations of STEM-PBL, situated learning theory, and social constructivism, this study proposes a conceptual framework that illustrates the relationships among the core constructs investigated (see Figure 2). At the center of the framework is the use of Minecraft as a game-based learning tool, which serves as the primary pedagogical intervention. This tool is hypothesized to influence two key domains: (1) student engagement and motivation in STEM subjects, and (2) understanding and application of Sustainable Development Goals (SDGs).

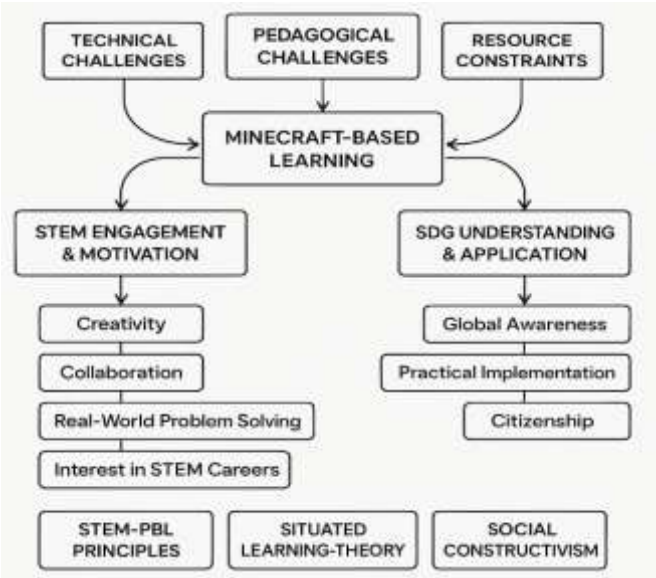

Fig.2 The conceptual framework of this study

These domains are interconnected through project-based learning activities that promote creativity, collaboration, and real-world problem-solving. The framework also incorporates contextual factors such as technical, pedagogical, and resource challenges, which act as moderating variables that may affect the effectiveness of the intervention. The expected outcomes include enhanced STEM learning, increased global awareness, and the development of 21st-century skills. This conceptual framework provides a structured lens through which the study's objectives, research questions, and findings are aligned, offering clarity and coherence to the research design.

METHODOLOGY

Study Participants

The participants in this study were primary school students aged 10-12 years old, enrolled in a STEM Club. A total of five students participated voluntarily in the project, with diverse backgrounds and varying levels of familiarity with Minecraft. Consent was obtained from students and their parents before participation in this study. Students were facilitated to design and build their vision of a "future school" using Minecraft. The theme was chosen to encourage creativity and forward-thinking, while integrating Sustainable Development Goals (SDGs) to promote global awareness.

In this study, students worked in groups to create their projects and prepared video presentations to explain each building's functions and its alignment with specific SDGs. The project was introduced to students, explaining the objectives, tasks, and the use of Minecraft. Students were divided into groups and given guidelines for their projects. Students spent four weeks designing and building their future schools in Minecraft. During this phase, they collaborated, researched, and applied STEM concepts to their designs. After four weeks, students prepared video presentations to explain their projects, focusing on the functions of each building and its alignment with the SDGs.

Data Collection

Data was collected through multiple methods to ensure a comprehensive analysis. Students recorded video presentations explaining their projects. These videos were analyzed for content related to STEM concepts and SDGs. Besides, students wrote reflections on their experiences, detailing what they learned and how they felt about the project. To get more data, observations were conducted to monitor student interactions, collaboration, and engagement during the project.

Data Analysis

The data collected was analyzed qualitatively using thematic analysis, which involved systematically identifying, analyzing, and reporting patterns within the qualitative data collected from video presentations, student reflections, and observations. Initially, meaningful segments of the data were coded, and these codes were grouped into broader themes [4]. The themes were reviewed and refined to ensure they accurately represented the data and were then defined and named to provide clear descriptions of each theme and its relation to the research questions. To ensure the reliability and validity of the identified themes, quality appraisal was conducted using the fixed criteria [19].

Experts were asked to evaluate the credibility of the identified themes based on the following criteria: (i) accuracy, (ii) clarity, (iii) relevance, and (iv) consistency. Each criterion was rated on a scale of 1 to 5, where 1 = Poor, 2 = Fair, 3 = Good, 4 = Very Good, and 5 = Excellent. This thematic analysis and quality appraisal ensured that the findings were trustworthy and meaningful, providing valuable insights into the educational benefits of using Minecraft in STEM education.

To assess student learning outcomes, a formative assessment approach was employed, focusing on creativity, collaboration, application of STEM concepts, and integration of SDG principles. Students were evaluated based on their video presentations, project design features in Minecraft, and written reflections. The assessment criteria included: (1) clarity and depth of explanation of STEM concepts, (2) relevance and

accuracy of SDG integration, (3) originality and feasibility of design, (4) evidence of teamwork and problem-solving, and (5) presentation quality. A formative assessment of the rubric is provided in Table 1.

Table 1. Formative Assessment Rubric for Student Projects

Criteria	Needs Improvement (1)	Developing (2)	Proficient (3)	Exemplary (4)
STEM Concept Understanding	Limited understanding of STEM concepts	Basic understanding of STEM concepts	Clear understanding of STEM concepts	Deep and thorough understanding of STEM concepts
SDG Integration	Minimal integration of SDG principles	Basic integration of SDG principles	Relevant and accurate integration of SDG principles	Comprehensive and insightful integration of SDG principles
Creativity and Design	Limited creativity and feasibility in design	Basic creativity and feasibility in design	Original and feasible design	Highly original and highly feasible design
Collaboration and Communication	Limited evidence of teamwork and communication	Basic evidence of teamwork and communication	Clear evidence of teamwork and communication	Exceptional evidence of teamwork and communication
Presentation Quality	Limited clarity and engagement in the presentation	Basic clarity and engagement in the presentation	Clear and engaging presentation	Highly clear and highly engaging presentation

FINDINGS

The results of this study revealed seven themes and twelve sub-themes, which were identified. The themes and sub-themes were examined and evaluated by experts. Table 2 summarizes the average ratings for each criterion based on the expert reviews. The quality appraisal findings from the expert review process provide strong evidence for the credibility of the identified themes, supporting the reliability and validity of the qualitative analysis. The evaluated themes and sub-themes were presented according to the research questions (See Table 3).

Table 2. Average Ratings for Each Criterion

Criterion	Average Rating (out of 5)	Level of Agreement
Accuracy	4.6	High
Clarity	4.4	High
Relevance	4.7	High
Consistency	4.5	High

Table 3. Emerging Themes and Sub-Themes

Research Questions	Emerging Themes	Sub-themes
The Impact of Using Minecraft to Build Future Schools on Students' Engagement and Motivation in STEM Subjects	Student Engagement	Active participation Collaborative learning Creativity and innovation
	Motivation in STEM	Interest in STEM subjects

		Self-efficacy in STEM tasks Long-term interest in STEM careers
Learning Outcomes of Integrating SDGs into a Minecraft-Based Project	Understanding of SDGs	Awareness of global issues Knowledge of specific SDGs
	Application of SDGs	Practical implementation in projects Real-world problem-solving
Challenges and Limitations Students Face When Implementing Such Projects	Technical Challenges	Access to technology Technical skills required
	Pedagogical Challenges	Curriculum integration Assessment methods
	Resource Constraints	Time limitations Budget constraints

The Impact of Using Minecraft to Build Future Schools on Students' Engagement and Motivation in STEM Subjects

The integration of Minecraft in building future schools significantly enhanced students' engagement and motivation in STEM subjects. Students' reflections revealed that active participation in hands-on activities within Minecraft's interactive environment kept them more involved compared to traditional classroom settings. For instance, one student noted, "I felt more engaged because I could build and see my ideas come to life, rather than just reading about them." Collaborative learning was another key factor, as students frequently worked in groups, sharing ideas and solving problems together. This was evident in a group presentation where students highlighted, "Working together in Minecraft helped us learn from each other and come up with better solutions." The creative freedom offered by Minecraft encouraged innovation, with students expressing excitement about experimenting with different designs and solutions (see Figure 3). One student reflected, "Minecraft allowed me to be creative and think outside the box, which made learning STEM subjects more fun and interesting."

Fig.3 An example of student creative solutions

Learning Outcomes of Integrating SDGs Into a Minecraft-Based Project

Integrating the Sustainable Development Goals (SDGs) into Minecraft-based projects led to significant educational outcomes. Students demonstrated a deeper understanding of global issues and the SDGs, as reflected in their presentations. One student explained, "Through our project, I learned about the importance of clean water and how we can create systems to manage it sustainably." The practical application of SDGs in their projects enhanced their problem-solving skills and real-world understanding. For example, a student group designed a sustainable city within Minecraft, incorporating renewable energy sources and efficient waste management systems (see Figure 4). They presented, "Our city project taught us how to apply SDG principles to create a more sustainable and livable environment." This hands-on approach not only increased their knowledge of specific SDGs but also fostered a sense of global citizenship and responsibility.

To further clarify the depth of SDG integration in student projects, we developed a detailed mapping of specific SDG targets to the features of students' Minecraft-based designs. While students demonstrated general awareness of sustainability themes such as clean water, renewable energy, and biodiversity, this table provides a more explicit alignment with the United Nations Sustainable Development Goals. Each project feature is linked to a relevant SDG target, illustrating how students applied sustainability principles in practical, creative ways. This mapping enhances the transparency and rigor of our analysis and underscores the educational value of integrating SDGs into project-based learning (see Table 4).

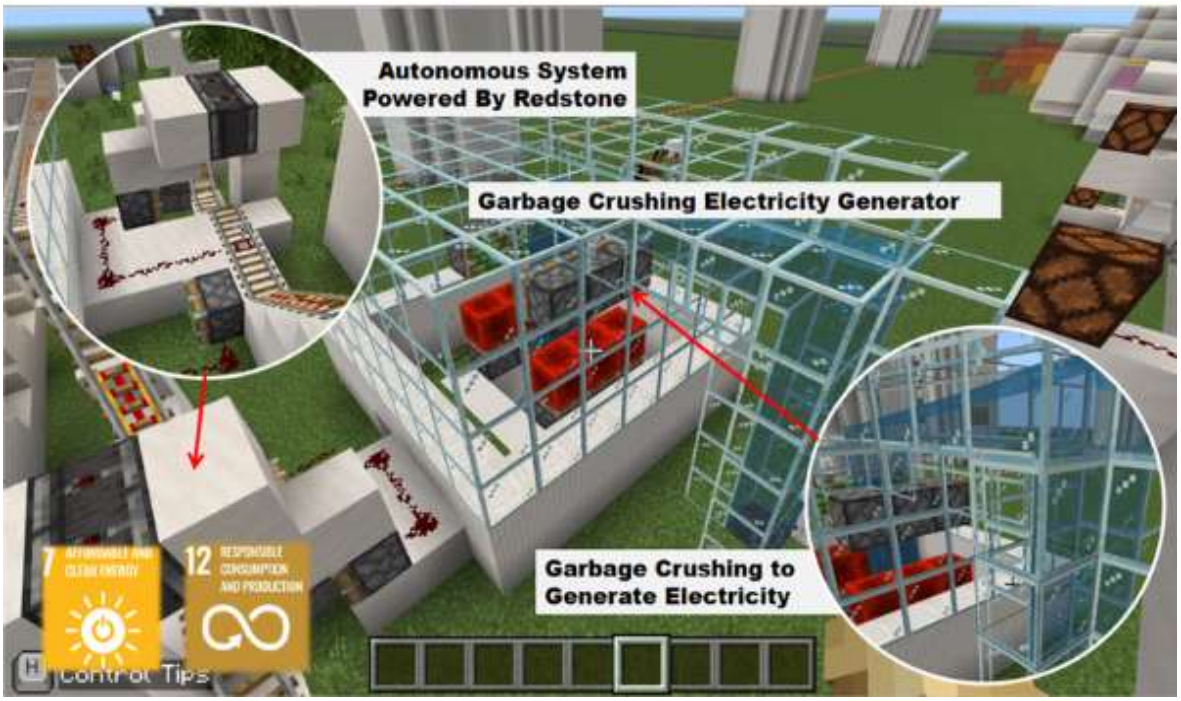

Fig.4 An example of renewable energy sources and efficient waste management

Table 4. Mapping of Student Project Features to Specific SDG Targets and Outcomes

SDG Number	SDG Target	Project Feature	Student Outcome
6	6.1	Clean Water Initiative	Understanding of water purification methods
7	7.2	Renewable Energy Project	Knowledge of solar and wind energy systems
11	11.6	Sustainable Cities Design	Skills in urban planning and sustainability
13	13.3	Climate Action Plan	Awareness of climate change mitigation strategies
15	15.1	Biodiversity Conservation	Appreciation of ecosystem preservation

Challenges and Limitations

Students encountered several challenges and limitations while participating in Minecraft-based educational projects. Technical challenges were prominent, with many students facing difficulties due to limited access to necessary technology, such as computers and reliable internet connections. One student mentioned, "I had to share a computer with my siblings, which made it hard to complete my project on time." Additionally, the need to develop new technical skills to effectively use Minecraft often caused frustration and delays, as reflected in a student's comment, "It took me a while to get used to all the features in Minecraft, and I fell behind compared to others who were more familiar with the game." Pedagogical challenges included balancing the demands of the Minecraft project with other academic responsibilities, with one student noting, "I enjoyed the project, but it was hard to keep up with my other subjects at the same time." Traditional assessment methods were not always suitable for evaluating Minecraft projects, leading to uncertainty about grading, as expressed by a student, "I wasn't sure how my teacher would grade my project since it was so different from our usual assignments."

Resource constraints also posed significant challenges, with students struggling to manage the substantial time required to plan, execute, and refine their projects. One student shared, "I spent so much time on my Minecraft project that I had less time for other homework and activities." Furthermore, the lack of adequate support from teachers or peers made it difficult for students to overcome challenges encountered during the project, as mentioned by a student, "I needed more help from my teacher to understand some parts of the project, but there wasn't always enough time for one-on-one support." These reflections highlight the various challenges and limitations students face when participating in Minecraft-based educational projects, underscoring the need for additional support and resources to create a more effective and supportive learning environment.

DISCUSSION

The results of this study contribute significantly to the theoretical frameworks of STEM-PBL, situated learning theory, and social constructivism. The STEM-PBL principles emphasize learning through engaging, hands-on projects that integrate science, technology, engineering, and mathematics. The Minecraft project, where students designed and built their vision of a future school, exemplifies this approach by fostering critical thinking, creativity, and real-world problem-solving. This aligns with recent research that highlights the effectiveness of project-oriented problem-based learning (POPBL) in enhancing students' critical thinking skills and achievement in STEM subjects [20].

This study found that active participation in Minecraft's interactive environment kept students more involved compared to traditional classroom settings. Collaborative learning was another key factor, as students frequently worked in groups, sharing ideas and solving problems together. The creative freedom offered by Minecraft encouraged innovation, with students expressing excitement about experimenting with different designs and solutions. These findings support the STEM-PBL principles' emphasis on engaging, hands-on projects that integrate STEM disciplines [23]. The use of Minecraft made STEM subjects more appealing to students, increasing their interest and self-efficacy in STEM tasks.

Exposure to STEM concepts through Minecraft sparked a long-term interest in STEM careers for many students. This aligns with the social constructivist principle that learning is a social process, as students worked together, negotiated meanings, and built knowledge collectively [2]. Situated learning theory [14] suggests that learning occurs best in context and through participation in authentic activities. The Minecraft project provided a situated learning experience, where students engaged in meaningful tasks that resembled real-world challenges, such as designing sustainable schools. This approach helped students see the relevance of their learning and apply their knowledge in practical, authentic contexts. Recent studies have shown that situated learning environments significantly improve students' reasoning and proof abilities in mathematics [6], supporting the idea that knowledge is best acquired in real-world settings.

Students demonstrated a deeper understanding of global issues and the Sustainable Development Goals (SDGs) in this study. The practical application of SDGs in their projects enhanced their problem-solving skills and real-world understanding. This hands-on approach not only increased their knowledge of specific SDGs but

also fostered a sense of global citizenship and responsibility. These results align with the situated learning principle that knowledge is best acquired in real-world settings [14]. Students applied their knowledge of SDGs in practical ways within their Minecraft projects, designing solutions that addressed real-world problems. This approach enhanced their problem-solving skills and real-world understanding.

The results of this study also provide practical implications for educators and policymakers. The integration of Minecraft in educational projects can enhance student engagement and motivation in STEM subjects, making learning more interactive and enjoyable. Educators should consider incorporating game-based learning tools like Minecraft to foster creativity and innovation among students. Additionally, the emphasis on collaborative learning and real-world problem-solving can help students develop essential skills for future careers in STEM fields. However, educators need adequate training and support to effectively integrate Minecraft into their curriculum. Schools must invest in technology and resources to provide all students with access to the necessary tools.

Addressing technical challenges, such as access to technology and the need for technical skills, is crucial for successful implementation. These findings reflect broader digital divide issues prevalent in Southeast Asia. Many rural and underserved communities across the region face infrastructural limitations that hinder equitable access to digital learning tools. Students from the richest households in Southeast Asia are nearly eight times more likely to be connected at home than those from the poorest households [24]. These disparities not only affect students' ability to participate in game-based learning projects like Minecraft but also exacerbate existing educational inequalities.

Addressing these challenges requires coordinated policy efforts to expand digital infrastructure, subsidize access to educational technology, and provide targeted teacher training. Research highlights the need for a balanced approach that includes both supply-side policies and demand-side strategies to close the digital divide [15]. By situating our findings within this wider context, the findings highlight the importance of systemic support to ensure that innovative pedagogies can be implemented inclusively and sustainably across diverse educational settings. In summary, the findings of this study contribute to the theoretical frameworks of STEM-PBL, situated learning theory, and social constructivism, while also providing practical insights for enhancing STEM education through innovative approaches like Minecraft-based projects. Addressing the identified challenges can help create a more supportive and effective learning environment for students, fostering their interest and success in STEM subjects.

RECOMMENDATIONS

Based on the findings, several actionable recommendations emerge. First, educators should consider integrating Minecraft and similar game-based tools into STEM curricula to foster creativity, collaboration, and real-world problem-solving. Professional development and training are essential to equip teachers with the skills needed to implement these tools effectively. Second, policymakers must address infrastructural and resource disparities, particularly in underserved regions, by investing in digital infrastructure and equitable access to technology. Third, future research should expand the scope of Minecraft-based learning by conducting longitudinal studies and comparative analyses across diverse educational settings. These efforts will deepen our understanding of the long-term academic and career impacts of game-based learning. Ultimately, this study contributes meaningfully to the body of knowledge by demonstrating the transformative potential of Minecraft in STEM education and global citizenship development.

CONCLUSION

In conclusion, this study explored the impact of using Minecraft to build future schools on students' engagement and motivation in STEM subjects, the learning outcomes of integrating Sustainable Development Goals (SDGs) into a Minecraft-based project, and the challenges and limitations faced by educators and students. The findings revealed that Minecraft significantly enhanced student engagement and motivation in STEM subjects through active participation, collaborative learning, and creativity. Students demonstrated a deeper understanding of global issues and SDGs, applying their knowledge in practical, real-world contexts. Technical, pedagogical, and resource challenges were identified as significant barriers to successful

implementation. This study involved a small sample size (n=5), which limits the generalizability of the findings. Despite this, the insights gained offer valuable implications for educational practice and future research.

The findings contribute to the STEM-PBL principles, situated learning theory, and social constructivism. The study supports the principles of engaging hands-on projects that integrate STEM disciplines. It also reinforces the principles of situated learning theory by demonstrating the effectiveness of learning in authentic, real-world contexts. Additionally, the study aligns with social constructivism by highlighting the importance of social interactions and collaboration in the learning process. The study highlights the potential of game-based learning tools like Minecraft to enhance STEM education and global awareness. Educators should consider incorporating such tools to foster creativity, collaboration, and real-world problem-solving skills. Future studies could also explore scaling the approach through multi-school or regional collaborations, enabling comparative analysis across diverse educational settings.

Addressing the identified challenges is crucial. Schools need to invest in technology, provide adequate training for educators, and develop suitable assessment methods to ensure successful implementation. Investigating the long-term impact of Minecraft-based projects on students' academic performance and career choices in STEM fields would provide valuable insights. Additionally, exploring the potential of other game-based learning tools and their effectiveness in different educational contexts could further enhance our understanding of innovative teaching methods.

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