

Construction Learning Revolution: Optimizing Student Engagement and Understanding through Game-Based Learning with Minecraft as a Learning Medium

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Abstract

In the digital era, innovative learning methods are key to increasing student engagement and understanding in engineering and construction. One of the increasingly emerging approaches is game-based learning (GBL), where games are used as interactive educational tools. This study explores the effectiveness of Minecraft: Education Edition in improving academic performance and engagement of students in the Construction Engineering and Management (CEM) Study Program at a university in Indonesia. This study used a mixed method, namely learning observation and questionnaire survey of students attending Minecraft-based lecture sessions. The findings of this study are presented in three main topics, namely the implementation of Minecraft: Education Edition as a learning medium, the Effectiveness of Minecraft as a Learning Medium for Construction Management, and implementation barriers. The results of this study are expected to provide insight into best practices in engineering education, especially in the application of interactive technology to improve learning effectiveness. This study also provides recommendations for higher education institutions to adopt game-based learning as part of innovative strategies in engineering learning. With increased student engagement and understanding through game-based simulations, Minecraft has the potential to be a revolutionary educational tool in the construction discipline.

Keywords: construction, engineering, game-based learning, Minecraft, student engagement

1. Introduction

Technology-based learning is increasingly developing, including in the construction discipline. Students from Civil Engineering, Architecture, and Construction Management study programs often experience challenges in understanding the concepts of planning, design, and management of construction projects practically. On the other hand, conventional learning methods based on face-to-face lectures and case studies are sometimes less able to increase student engagement and in-depth understanding.

Generation Z, who grew up in the digital era, has unique characteristics that affect student engagement and performance at the undergraduate level. They tend to be more familiar with technology, rely on online learning resources, and prefer interactive learning methods over traditional approaches [1]. This encourages educational institutions to adopt innovative strategies such as project-based learning, gamification, and the use of technology, such as virtual reality, as a tool for academic collaboration [2]. However, challenges such as digital distractions and a lack of time management skills can also affect their

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academic performance. Therefore, an adaptive and technology-based educational approach is needed to improve the engagement and academic achievement of Generation Z students.

Game-based learning (GBL) has been shown to increase student learning motivation, conceptual understanding, and engagement [2-3]. One of the games that has the potential to be used in construction education is Minecraft: Education Edition, which allows students to explore, design, and build virtual structures collaboratively. Therefore, this study focuses on the application of Minecraft as a learning medium to improve the academic performance and engagement of construction students, especially in a Construction Engineering and Management (CEM) study program.

This study aims to (1) evaluate the effectiveness of game-based learning using Minecraft in improving the understanding of construction management and engineering concepts, (2) analyze the impact of Minecraft use on student engagement, and (3) provide recommendations regarding the implementation of Minecraft as part of the CEM curriculum. This study examines the use of Minecraft in the context of higher education. Different from previous studies, this research combines a case study approach through learning observations supplemented by a questionnaire survey to measure student engagement. The case study was conducted in a university environment in Indonesia, which still lacks research related to game-based learning (GBL). Thus, this study is expected to contribute by providing new insights into the effectiveness of Minecraft in improving the quality of learning in the construction discipline. In addition, this study also provides empirical data that can be a basis for educational institutions in designing innovative learning strategies. Furthermore, this study also supports the adoption of technology in higher education, especially in the field of construction management.

2. Literature Review

2.1 Game-based learning

Game-based learning (GBL) is a learning method that utilizes game elements to increase engagement and learning effectiveness. Several studies have shown that GBL can improve students' memory, motivation, and problem-solving skills [2]. GBL is a pedagogical approach that integrates game elements into the learning process to increase student engagement and understanding. It can be done using various methods through visual and auditory stimuli to provide education to students [4]. According to Koivisto et al. [3] and Septianing et al. [5], GBL can increase learning motivation because it offers a challenging, fun, and immersive interactive experience. Several studies have shown that the use of games in learning allows students to experience real-world situations virtually, thereby improving problem-solving and decision-making skills [6]. In addition, GBL is also considered capable of accommodating various learning styles of students, both visual, auditory, and kinesthetic, thus creating a more effective and inclusive learning experience [7].

In the context of engineering and construction education, GBL has been applied in various forms, including simulations and virtual environments. One successful example is the use of Minecraft: Education Edition, which allows students to design and build structures collaboratively in a digital environment [8]. Research by Sujithra & Banu [2] shows that the use of games in engineering education can increase student engagement, improve knowledge retention, and help them understand abstract concepts more easily. In addition, GBL also facilitates project-based learning, where students can develop practical skills through hands-on exploration and experimentation in the virtual world [9-11]. With this approach, students not only gain theoretical understanding but also deeper practical experience related to construction design, planning, and management.

The benefits of GBL in engineering education are manifold. In addition to increasing engagement and motivation to learn, this method also allows students to learn in a safe environment without real consequences for mistakes made [12]. Game-based learning also supports the development of collaborative, communication, and critical thinking skills [10], which are very important in the construction industry. However, despite its many benefits, there are challenges in implementing GBL in higher education. Some of these include limited technological infrastructure, resistance from lecturers who are not familiar with this

method, and the need for game design that is in line with the curriculum [13]. In addition, the effectiveness of GBL depends heavily on the balance between educational aspects and game elements so that it is not just entertainment without significant learning impact. Therefore, research is needed to understand how GBL can be effectively integrated into engineering curricula (in this study context, focusing on CEM program), and how these obstacles can be overcome.

2.2 Minecraft in engineering and construction education

As technology advances in education, Minecraft: Education Edition has been used as an innovative learning tool across disciplines, including computer science, and construction [14]. As a simulation and exploration-based platform, Minecraft allows students to design, build, and manage projects in a virtual environment that closely approximates real-world conditions. According to research by Ellison and Evans [15], the use of Minecraft in education can increase student engagement, understanding of spatial and technical concepts, and creative and critical thinking skills. This makes Minecraft a potential medium for teaching technical and managerial skills in the construction field.

In Civil Engineering and Architecture study programs, Minecraft: Education Edition is used to simulate the design and construction process of structures. Students can learn the principles of building design, construction materials, and the environmental impacts of various designs created in the game [16]. With a block system that resembles real-world construction units, students can explore various construction methods and understand technical aspects such as structural loads, material efficiency, and spatial layout [17]. In addition, this platform also allows students to work in teams and develop collaborative skills in completing complex construction projects.

In the field of construction management, Minecraft offers simulations that can be used to understand project management, construction workflows, and resource management. A study by De Weck et al. [18] showed that simulations in Minecraft can help students learn the concepts of project planning, task distribution, and data-based decision-making. In this context, students can be given construction project scenarios with budget and time constraints, so that they can practice managing projects more realistically. With the collaborative features in Minecraft, students can also experience the dynamics of teamwork and communication that often occur in real construction projects [16].

Despite its many benefits, challenges in implementing Minecraft as a learning tool in construction study programs remain. One of the main obstacles is the readiness of lecturers to integrate this game into the curriculum, because it requires technical understanding in the design of learning simulations. In addition, there is a concern that students may focus more on the game aspect than on the academic goals to be achieved. Therefore, it is important to design Minecraft-based learning with a clear structure, including specific learning objectives and appropriate evaluation methods. Thus, the use of Minecraft in construction education can be more optimal in increasing students' understanding of the world of construction, both from a technical and managerial perspective.

2.3 Engagement and performance in game-based learning

Student engagement is closely related to learning outcomes. The engagement model in digital learning involves cognitive, emotional, and behavioural aspects. Several studies have shown that the use of interactive technology can improve student engagement and academic outcomes [1, 19]. Student engagement in learning is a key factor contributing to their academic achievement [10]. Engagement can be categorized into three main aspects: cognitive, affective, and behavioural. Technology-based learning has been shown to increase student engagement by providing interactive and immersive experiences that are difficult to achieve with conventional learning methods [5]. In the context of higher education, especially in engineering and construction, technology can be used to create a more engaging, challenging, and safe learning environment, helping students understand complex concepts through computer-based simulations and visualizations.

Game technology has been widely used in education to improve student academic performance. One increasingly popular approach is game-based learning (GBL), which combines game elements with learning objectives [10]. Research shows that GBL can improve students' conceptual understanding, critical thinking skills, and problem-solving abilities [13]. In the field of construction engineering, simulation-based games such as Minecraft allow students to explore various construction methods, understand civil engineering principles, and develop collaborative skills in a virtual environment that mimics real-world conditions [20].

Utilizing game technology in construction education can help students understand the technical and managerial aspects of construction projects. With game-based simulations, students can visualize the planning and construction of projects in a safe and flexible environment, without the risk of costs or fatal errors that occur in real-world projects [12]. In addition, collaborative features in games allow students to work in teams, simulating the communication and coordination challenges that often occur in the construction industry. By increasing engagement through technology-based learning, construction students can gain a more effective learning experience, improve their understanding of the material, and develop skills relevant to industry needs.

3. Method

This study uses a case study approach with observation and questionnaire survey methods. The research design by combining these two methods can provide a more comprehensive understanding of the game-based learning model applied at a private university in Jakarta. Several case studies related to learning models with similar research designs in engineering study programs have been conducted by Patil and Dharwadkar [1], Sujithra and Banu [2], Hansen and Rostiyanti [21], Rahane et al. [22].

The participants of this study are construction students from a private university in Jakarta, Indonesia, who are taking the Integrated Construction Project Modeling course. This course is offered in the short semester (July – August 2024), so only six students participated in this GBL pilot project. This research has received research ethics approval from LPPM Podomoro University No. LPPM/RE/037.2/24.

The first data collection method is learning observation, which is conducted during several lecture sessions using Minecraft: Education Edition as a learning medium. In this method, direct observation of student activities during the learning process will be conducted. Authors will pay attention to student involvement and interaction with various elements in the game, such as how they collaborate in building structures, completing assigned tasks, and interacting with lecturers and fellow students. This observation aims to measure the level of student engagement, namely the extent to which they actively participate and interact in Minecraft-based learning.

The second data collection method is a questionnaire survey, which will be given to students after they have participated in Minecraft-based learning. This questionnaire is designed to dig deeper into students' experiences during learning, with a focus on measuring their engagement and understanding of the material that has been taught. The questions in the questionnaire will cover various aspects, such as the level of relevance of using Minecraft as a learning tool, the benefits of implementing Minecraft, and the obstacles that occur during the GBL process. These two data collection methods complement each other in providing a more holistic picture of the effectiveness of implementing and using Minecraft in learning.

For the questionnaire survey method, data analysis will be carried out quantitatively using descriptive statistical techniques, namely mean and standard deviation (SD). Mean is a value obtained by adding up all the data in a group and dividing it by the number of data. The mean describes the middle value that represents the data as a whole. Standard deviation is a measure that shows how far the data values are spread out or vary from the average. The larger the standard deviation, the greater the variation or difference between the data and the average. Conversely, the smaller the standard deviation, the denser

the data is around the average. Descriptive statistical analysis is commonly used to summarize the main characteristics of a dataset and has been widely used in several previous publications [21, 23].

4. Results and Discussion

4.1 Implementation of Minecraft education

Integrating Minecraft: Education Edition into the CEM curriculum requires careful planning so that learning objectives can be achieved optimally. Lecturers must design teaching strategies that not only rely on the game aspect but also ensure that activities in Minecraft are in line with the competencies to be achieved. The first step is to include Minecraft as part of the Semester Learning Plan (RPS/*Rencana Pembelajaran Semester*) by determining the appropriate courses, such as Construction Project Management or Building Engineering. In the RPS, lecturers need to determine specific learning outcomes, such as understanding the concept of building structures, calculating material requirements, and project management simulations. In addition, Minecraft can be used as a tool in project-based learning methods, where students are tasked with designing and building a digital model of a particular construction project. In the case study conducted, GBL with Minecraft was applied to the Integrated Construction Project Modeling course, with four credits. In the RPS, the General Learning Outcomes are to train students in decision-making, critical thinking, and being able to communicate effectively. Meanwhile, the Specific Learning Objectives are:

1. Able to quantify the volume of work in a construction project (quantification).
2. Able to calculate the project budget plan accurately (bill of quantities).
3. Able to develop a construction project schedule plan accurately (scheduling).
4. Able to develop a quality assurance plan.
5. Able to identify and develop a risk management and Health, Safety, and Environment (HSE) plan.

In the learning method, lecturers can adopt a case study and experiment-based approach in Minecraft. Students can be given a construction project scenario, such as designing an environmentally friendly building or simulating project management with limited resources. The learning process can be divided into several stages, starting from understanding the initial concept and exploration in Minecraft to discussion and reflection on the results obtained. Collaboration is also an important element in the application of Minecraft, where students can work in groups to build projects together, simulating teamwork like in the real world. Lecturers act as facilitators who guide discussions and provide feedback on the design and management strategies used by students.

In the case study conducted, the authors/lecturers have set the rules of the game in advance, namely:

1. Cost variance should not be more than $\pm 8\%$. If the remaining budget is greater than 8%, it is overpriced; if it is less than 8%, it is less effective in using the existing budget. Don't run out of money, which means you have lost money.
2. A fine (liquidated damage) for late completion of 1% per day.
3. A fine (liquidated damage) due to work accidents or other preventable incidents of 5% per incident, and damage due to incidents must be repaired/restored to its original condition at the contractor's expense.

During the game, there is a feature that facilitates online interaction between the lecturer as administrator and students (Fig. 1). Furthermore, the learning process stage is divided into two, namely the planning and design stage, and the implementation stage. The following is a detailed explanation of the two learning stages that have been explained to the students.



Fig. 1 Students can interact simultaneously online with lecturers (facilitators) as administrators

1. Design and planning stage

- a) Students design buildings in creative mode; they determine the shape and dimensions of the building and choose the type of building material.
- b) Based on the building design, students do the following:
 - Calculate the quantity of materials needed to be procured and/or removed from the site (there is cut & fill work where students need to condition uneven land contours).
 - Estimate the cost of the construction project to be then submitted to the project owner (played by the lecturer) as a tender/offer. The estimated costs are direct costs and indirect costs.
 - The direct cost of the project is calculated from the price of the material and the equipment in the game. To plan the direct cost budget for the project, students need to be informed by the lecturer (facilitator) of the price range for materials and equipment, not a fixed price. The price of materials, equipment, food, and other items will only be known to students when starting the implementation stage.
 - Indirect costs are needed in planning because, in this game, there is a mechanism that makes the player's character hungry. Hunger will cause the game character to move more slowly and can reduce the character's health. For this reason, players need to buy food to keep their characters from starving (Fig. 2).



Fig. 2 "Hunger bar" which indicates the player character is starting to experience hunger

- Estimating the duration (schedule) of the construction project based on the construction method they have set. There is a day-night cycle mechanism in the game. The game's duration can be calculated automatically and compared to the team's schedule plan.
- Developing a quality plan for their construction project and determining inspection milestones with the Owner (lecturer).
- Planning risk management and HSE from identifying and analyzing to budgeting costs and time for implementing risk responses. Major risks that can arise in the game include:
 - The player character can have an accident, such as falling from a height, when working at a height. Every time there is an incident of falling from this height, the player's team is fined according to the provisions at the beginning. This encourages players to plan safer work methods and budget costs to buy scaffolding in the game.
 - Non-Playable Characters (NPCs) can attack, injure players, and destroy buildings and the environment around the project. All forms of damage caused by these NPCs are the full responsibility of the team. If an incident like this occurs, the team must repair the damage, both inside and outside their project.

2. Implementation stage

- a) Students submit their project management plan and project budget plan (as a bid estimate). This becomes their score (Fig. 3).



Fig. 3 The project budget plan submitted by students appears in the form of a “BUDGET” score on the right side of the screen

- b) Students carry out the construction process according to the plans and designs they have made. Building materials and equipment used for construction can be purchased virtually in the game. The lecturers have created the material and tool purchasing system. This system allows players (students), when making a purchase, to be automatically given the purchased material in a certain amount, and their BUDGET score will be reduced according to the purchase price of the materials and equipment (Fig. 4).
- c) In implementing the project, control and supervision are also run to evaluate the project's progress.

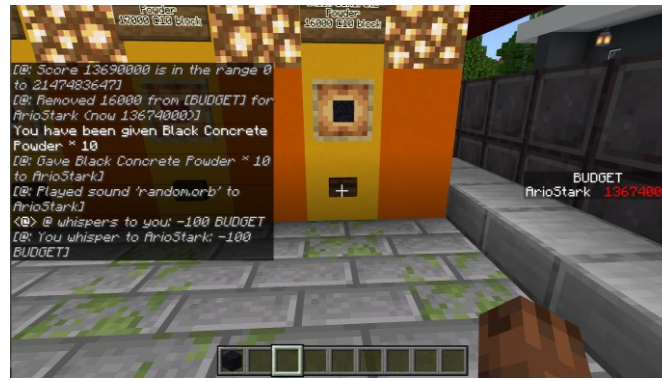


Fig. 4 The BUDGET score is automatically reduced, and the player receives the purchased materials automatically

Minecraft-based learning evaluation should cover various aspects, both in terms of conceptual understanding, creativity, and students' collaborative skills. Evaluation methods can be carried out through a combination of project-based assessment, student engagement evaluation, and reflective questionnaires. Lecturers can provide assessment rubrics that include criteria such as design accuracy to construction principles, efficient use of resources in project simulations, and students' ability to work together and complete the challenges given. In addition, students can be asked to compile a report or presentation on their project in Minecraft, explaining how construction engineering and management concepts are applied in the designs they have created.

In the case study conducted, the evaluation was carried out in stages, starting from a project-based assessment of the GBL results, student engagement observations, and reflective questionnaires. Project-based competency assessments are seen from the budget score and game duration of each student. This budget score reflects the management of the project by students in overcoming resource limitations and risks that may occur during the implementation of the work. The duration of the game reflects the student's time management by paying attention to productivity in the day-nighttime cycle that has been set in the game.

Evaluation of student engagement is based on two methods, namely direct observation during the learning process and analysis of student attendance. Direct observation was conducted by observing the level of student participation in discussions, questions and answers, and learning activities through the interaction features in Minecraft. This participation reflects the level of student attentiveness to the work. In this case study, all students actively engaged in the interactions. Likewise, the analysis of student attendance showed that all students attended complete lectures in 16 sessions (Fig. 5).

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Students

No	Students	Sessions															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Bernad Goklas Damora Siturus 22190007	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
2	Kelvin 22210001	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
3	Loventil Sutanto 22210002	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
4	Nasori Veresca 22210003	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
5	Fransiskus Xaverius Krisanda Budiman 22210004	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
6	Nathania Sasi Paatka 22210005	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●

Fig. 5 The full attendance of students shows their enthusiasm for participating in this learning

To ensure the sustainability and effectiveness of Minecraft implementation in learning, lecturers can hold evaluation and reflection sessions at the end of the semester to assess the advantages and challenges of this method. Input from students regarding their experiences in using Minecraft can be used as material for improvement for future curriculum refinement. In addition, collaboration with other faculties or institutions that have successfully implemented game-based learning can be a source of insight for lecturers in developing more innovative.

4.2 Effectiveness of Minecraft as a learning medium for construction management

Table 1 presents the relevance of GBL (in this case, Minecraft) to the principles of construction management as measured by a Likert scale of 1 (totally irrelevant) to 5 (totally relevant). This finding shows a positive response from students regarding the relevance of GBL to the principles of construction management, considering that all indicators have a mean value above three. Minecraft, as a game that combines creativity and construction, has a strong relevance to the principles of construction management. In this game, players are faced with the task of planning, designing, and building structures in a virtual world, which reflects the real-world construction process. Principles such as careful planning, resource management, time management, and risk evaluation can be applied in Minecraft. For example, players must take into account the availability of building materials, manage time to complete the project and plan the design to be efficient and functional. Thus, Minecraft is not only a game but also a simulation tool that illustrates how the basic principles of construction management can be applied in a simpler but still relevant context.

Table 1 The relevance of Minecraft-based learning to construction management principles

No	Indicators	Mean	SD
1	Is the GBL relevant to the principles of construction work quantification?	4	0.63
2	Is the GBL relevant to the principles of construction cost management?	4.2	0.98
3	Is the GBL relevant to the principles of construction project scheduling?	4.2	0.40
4	Is the GBL relevant to the principles of construction quality management?	3.6	1.20
5	Is the GBL relevant to the principles of construction risk management and HSE?	3.6	1.02
6	Is the GBL relevant to the principles of integrated construction project management?	4.8	0.40

Table 2 shows the advantages of GBL compared to conventional learning methods. A Likert scale of 1 (strongly disagree) to 5 (strongly agree) was used to measure it. Regarding the four indicators of GBL advantages that were measured, all received high positive responses (with a mean value above four). One of the advantages of GBL is the ability to increase student engagement [16]. In traditional learning systems, such as lectures and text-based learning, students are often passive and less involved in discussions. By using Minecraft, students become more active in the learning process because they can explore, interact, and collaborate in a virtual environment that resembles real-world conditions. A study by Sugianto [24] showed that the use of games in education can increase students' learning motivation because they feel more emotionally and cognitively involved in completing the tasks given. This is an advantage of game-based learning, which emphasizes the interactive learning process [25].

Table 2 The advantages of Minecraft-based Learning

No	Indicators	Mean	SD
1	Does the GBL improve the engagement and interaction between fellow students and lecturers?	4.8	0.40
2	Does the GBL increase your confidence in working together?	5	0.00
3	Does the GBL improve your ability to make decisions?	4.6	0.49
4	Does the GBL improve your ability to think critically?	4.4	0.80

In addition, Minecraft encourages increased cooperation and communication between students in completing construction tasks. In conventional learning methods, students usually learn individually or in small groups without any real simulation experience. With Minecraft, students can collaborate on digital construction projects, where they must design, build, and manage projects together [16, 18]. This experience not only helps them understand the concept of construction management but also trains decision-making and critical thinking skills that are very important in the industrial world. This kind of collaboration simulates real-world conditions, where construction professionals must work in multidisciplinary teams to complete complex projects.

Table 3 presents the findings related to the extent to which GBL helps students understand construction management principles. Perception is measured on a Likert scale of 1 (very unhelpful) to 5 (very helpful), and all seven indicators received positive responses. In terms of understanding construction concepts, Minecraft offers advantages over conventional methods that only rely on textbooks or two-dimensional images. With its simulation and exploration features, students can visualize design, planning, and construction management concepts more concretely. For example, when learning about building structures, students can directly build models in Minecraft and test various design configurations to see their impact on building stability. Research by Carbonell-Carrera et al. [20] revealed that game-based learning environments can improve understanding of spatial and engineering concepts because students can experiment directly without fear of making mistakes that have major impacts, as is often the case in physical laboratory practices.

Table 3 The helpfulness of Minecraft-based learning in facilitating understanding

No	Indicators	Mean	SD
1	Does the GBL make it easier for you to understand the principles of construction quantification?	4.4	0.49
2	Does the GBL make it easier for you to understand the principles of construction cost management?	4.4	0.80
3	Does the GBL make it easier for you to understand the principles of construction project scheduling?	4	0.89
4	Does the GBL make it easier for you to understand the principles of construction quality management?	3.6	1.20
5	Does the GBL make it easier for you to understand the principles of construction risk management and HSE?	4.6	0.49
6	Does the GBL make it easier for you to improve your communication skills within the project team?	5	0.00
7	Does the GBL make it easier for you to understand the principles of integrated construction project management?	4.4	0.49

In addition to understanding design and planning, students can also use Minecraft to simulate construction project management, including resource allocation and work scheduling [18]. In conventional methods, project management concepts are often only learned through case studies in class, which can feel abstract and less applicable. With Minecraft, students can experience firsthand how changes in planning can affect project efficiency. In the case study conducted in the MRK study program, there are arrangements related to risks such as work accidents or damage caused by NPCs. This mechanism can test resource and risk management strategies in projects that students are working on. In this way, Minecraft not only improves students' conceptual understanding but also helps them develop critical thinking and decision-making skills in complex situations.

With all its advantages, Minecraft-based learning has proven to be more effective than conventional learning methods in increasing student engagement and understanding in the construction discipline. However, its effectiveness is highly dependent on the right learning design and the active involvement of lecturers in guiding the learning process. With good planning, the use of Minecraft in construction engineering and management education can be an innovative solution to produce graduates who are better prepared to face the challenges of the world of work.

4.3 Implementation barriers

Although GBL offers various benefits in increasing student engagement and understanding, its implementation in higher education still faces various obstacles. One of the main challenges is the readiness of the technological infrastructure in educational institutions. Not all universities have adequate facilities, such as computers with high specifications, stable internet connections, and software licenses needed to run Minecraft: Education Edition or other game platforms. Without good infrastructure support, the effectiveness of game-based learning can be reduced, especially if students must use their own

devices that may have technical limitations [26]. This can cause students to be frustrated rather than engaged in learning [18].

Table 4 presents students' perceptions regarding obstacles in implementing GBL as measured by a Likert scale of 1 (very obtrusive) to 5 (very unobtrusive). Of the three indicators of obstacles, two received positive responses, which means that they are not too challenging for students in implementing GBL, namely accessibility and hardware issues. However, for internet connection disruption, the mean value was 1.2, indicating that this was considered 'obtrusive' in the implementation of GBL during the lecture process. Thus, issues related to internet connection need to be given special attention in the implementation of GBL in the future.

Table 4 Implementation barriers

No	Indicators	Mean	SD
1	How much are you bothered by the following accessibility issues, such as brightness, sound quality, motion sickness, etc.?	3.8	1.17
2	How much are you bothered by internet connection issues when they occur?	1.2	0.40
3	Do you often experience hardware issues when playing this construction simulation game?	4	0.89

In addition to the obstacles from the student perspective, there are also obstacles experienced by the research team as lecturers who facilitate this GBL. Lecturers' adaptation to game-based learning methods is a challenge. Many lecturers who are accustomed to conventional learning methods find it difficult to integrate games into their curriculum. This is due to the lack of experience in using game technology as a learning tool and limited time to develop materials that are in accordance with the GBL method. According to Utami et al. [27], the effectiveness of game-based learning is highly dependent on the ability of educators to design learning activities that are in line with academic objectives, not just relying on the entertainment aspect of the game itself. Therefore, special training is needed for lecturers so that they can understand how to optimize games in learning and adjust academic evaluation methods that are in accordance with this new approach [26].

Adaptation to game-based learning by students can also be a challenge that lecturers should consider. Although the current generation is more familiar with technology, not all students have experience using educational games in an academic context. Some students may have difficulty understanding the game's mechanics or feel that the game is too complex compared to conventional learning methods. Thus, efforts are needed to design a more inclusive GBL by considering student characteristics [18, 28]. In addition, there is a risk that students focus more on the game aspect than the learning objectives to be achieved. Marklund & Alklind Taylor [26] argue that without a clear learning structure, game-based learning can be a distraction rather than an effective tool for improving conceptual understanding. Another challenge is how to assess students' academic achievement in game-based learning [26]. In a higher education system that still prioritizes traditional evaluation methods such as written exams and paper assignments, measuring student success in GBL requires a different approach. Lecturers must develop assessment rubrics that not only assess the final results of projects created in the game, but also the thinking process, creativity, and collaborative skills developed during the learning process. The difficulty in adjusting this assessment system can be an obstacle to the widespread implementation of GBL in higher education. This is something that has not been fully done by the research team in the case study in the MRK study program because they are still looking for the right way to assess student abilities according to the competencies to be achieved. This leaves room for improvements in the development of GBL integration through Minecraft in the future for the research team.

To overcome the various challenges above, a comprehensive strategy is needed, including investment in technological infrastructure, lecturer training, and a structured learning approach so that games can truly be used as effective educational tools. With good preparation, game-based learning can be an innovative solution to improving the quality of learning in higher education, especially in the fields of engineering and construction.

4.4 Research implications

This study has significant implications for the development of technology-based curricula in higher education, especially in the fields of engineering and construction. With the increasing digitalization in the construction industry, the integration of technology in learning has become a necessity that cannot be ignored. The use of Minecraft: Education Edition as a game-based learning tool shows that technology can increase student engagement and their understanding of design concepts and construction management. Therefore, higher education institutions need to start designing more adaptive curricula by incorporating game-based learning elements as part of active learning strategies. Technology-based curricula not only increase graduates' competitiveness in the workforce but also prepare them to face the challenges of an increasingly digitalized industry.

In addition, this study opens up opportunities to expand the use of Minecraft to other more specific construction fields. So far, Minecraft has been used more in teaching basic design and project management, but its potential can be developed for more complex fields such as structural engineering, drainage system simulation, and sustainability management in construction. With interactive simulation and visualization features, students can test various scenarios in sustainable construction, such as calculating energy efficiency in buildings or the environmental impact of materials used through construction waste management. Thus, Minecraft not only serves as a tool to help understand basic concepts but also as an innovative platform for exploration and research in various aspects of construction engineering.

Furthermore, the implications of this study can also be applied in improving collaboration-based learning methods. The construction industry relies heavily on teamwork and effective communication between various parties, including clients, engineers, architects, and project managers. Through the use of Minecraft, students can practice in a virtual work environment where they must coordinate the planning, design, and execution of projects. This approach reflects the reality of the construction industry, where BIM (Building Information Modeling) technology and digital collaborative platforms are increasingly becoming the standard in modern construction projects. Thus, educational institutions can use these findings to develop more practical and relevant learning methods to meet today's industry needs.

Finally, this study also provides insights for policymakers in higher education to further consider the integration of game technology in learning, not only in the field of construction engineering but also in other disciplines. A technology-based approach can be a solution to overcome various challenges in conventional learning, such as low student engagement and difficulty in understanding abstract concepts. With support from universities in the form of technological infrastructure and training for lecturers, the implementation of game-based learning, such as Minecraft, can be optimized to create a more interesting, effective, and modern learning experience.

5. Conclusions

Based on the results of this study, Minecraft: Education Edition has great potential as an innovative learning tool in construction engineering education. Compared to conventional learning methods, game-based learning using Minecraft can increase student engagement and encourage them to be more active in discussions, exploration, and collaboration. In addition, the interactive simulation offered by Minecraft helps students understand the concepts of design, planning, and construction management more effectively. Thus, the implementation of game technology in higher education can be a solution to overcome various learning challenges, especially in the field of engineering, which requires a visual and practical approach.

However, the implementation of Minecraft in learning still faces several obstacles, including infrastructure readiness, lecturer and student adaptation, and an evaluation system that is in accordance with the game-based learning method. Therefore, support is needed from educational institutions to develop a more structured technology-based curriculum. Training for lecturers in designing and managing game-based learning is also a key factor, so that this method can be implemented effectively and sustainably. In addition, periodic evaluation of the effectiveness of Minecraft-based learning must be carried

out to ensure that this technology really has a positive impact on student understanding and skills.

Through a case study on a CEM study program at a private university in Jakarta, this study can be a reference for lecturers in designing and integrating Minecraft: Education Edition in construction project management learning. The results of observations and reflections show the effectiveness of using Minecraft as a learning medium that increases student motivation and engagement. As a suggestion for further research and development, it is necessary to explore the application of Minecraft in more specific aspects of construction engineering, such as structural engineering, sustainability-based project simulations, and integration with Building Information Modeling (BIM) technology. In addition, further studies can focus on how the game-based learning approach can be applied in various other engineering disciplines and how to develop a more comprehensive evaluation method to assess the success of game-based learning, such as Minecraft. With more in-depth research, the use of Minecraft and similar technologies can continue to develop as an innovative learning strategy that is relevant to the needs of modern construction education.

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