# Crafting An Approach to Cultivate Engineering Competencies for Undergraduate Students in Construction Engineering with Minecraft

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## Abstract

The construction industry, like other fields of expertise, necessitates skills beyond mere engineering knowledge and skills. In today's competitive world, individuals must enhance their abilities not only in their area of study, but also in personal and interpersonal skills that can have a positive impact on their academic and workplace performance. Engineers are required to identify problems, find solutions, and make the most efficient decision and overcome obstacles to ensure project success. Although these are all essential skills, at the same time, engineers need to collaborate with others which require additional skills like effective communication. Unfortunately, these skills are often not fully developed during undergraduate studies, leaving construction engineering students and entry-level engineers with challenges in this area. The objective of this research paper is to conduct case studies that will evaluate a novel approach to teach engineering students how to collaborate, communicate effectively, listen actively, think logically, and make sound decisions to solve the problems. This will be achieved by utilizing Minecraft: Education Edition (MinecraftEdu) as a game-based learning platform. Students from construction engineering field were required to work in groups to build a one-story single-family home in MinecraftEdu. Based on the study's two major competencies; collaboration and problem solving, this active learning approach aims to evaluate students' behavior and attitudes in practicing these competencies and relevant skills while working in a group. Two distinct evaluation strategies were utilized to assess the effectiveness of this method as well as participants' feedback. Results revealed that well-designed tasks in MinecraftEdu can help students practice engineering and interpersonal competencies, as the participants demonstrated an improved willingness to communicate and collaborate in solving problems. This study also suggests that MinecraftEdu has the potential to effectively support teaching and enhance student learning in engineering practices.


## Introduction

The construction industry is known for its high labor intensity and diverse range of job types, which require varying levels of communication skills. From the management team to engineers, superintendents, skilled workers, and front-line workers, effective communication is crucial to ensure that projects are completed on time, within budget, and to the desired quality standards. Effective collaboration between managers and workers is crucial to prevent accidents and resolve issues at the construction job site [1]. As a major contributor to the global economy, the construction industry faces numerous challenges such as declining productivity, workplace safety, and labor disputes [2]. Many of these issues can be addressed through effective management and problem-solving skills [2]. Technical knowledge is the most crucial characteristic for a competent civil and construction engineer, followed by decision-making skills, knowledge of teamwork, planning and scheduling abilities, and leadership skills [3]. According to research, the most commonly identified competency categories for construction managers are technical knowledge, leadership skills, effective communication, management and organization, planning abilities, teamwork, and a strong sense of determination [2]. These

competencies are critical for ensuring successful construction projects delivery. However, despite ongoing criticism, engineering programs in undergraduate studies continue to prioritize technical skills over non-technical skills, resulting in insufficient attention to the latter and lack of related competencies in entry-level engineers [4], [5].

University students who major in construction engineering typically manage construction sites after graduation. There is a growing recognition that higher education institutions must place greater emphasis on developing generic skills among students [7]. These generic soft skills include the ability to work effectively in a team, communicate clearly, engage in multidisciplinary teamwork, collaboratively build knowledge, and solve complex problems [7]. The study indicated that there are two perspectives among students regarding engineers' ability to move from technical to managerial positions [4]. Some students believe that engineers can make the transition easily, while others have acknowledged the lack of communication skills among engineers [4]. At the same time, Employers now expect 21st-century engineers to have a range of soft skills, such as communication, teamwork, management, and entrepreneurial abilities, to succeed in their entry-level jobs [4]. Although undergraduate studies often overlook the importance of these critical soft skills, it is crucial to provide additional support and resources to help construction engineering students develop and excel in the competencies mentioned above.

Game-based learning, particularly the use of digital games, can assist educators in creating teaching approaches based on gaming [8]. It has been demonstrated that game-based learning can enhance engagement, retention, interest, motivation, confidence, and overall learning outcomes [11]. Gamification of non-game settings such as engineering field, particularly in educational contexts, has gained popularity in the past decade [9]. Several educational areas have applied gamification as an effective educational solution. These areas include occupational safety, construction methods, lean construction, sustainability, project management, project operations, economic decision analysis, and communication [8]. Studies in these areas aimed to facilitate learning and operations through gamified solutions. Research in higher education for science and engineering fields has also indicated the effectiveness of gamification elements in increasing student engagement and improving overall performance [10]. Some games, such as Minecraft, have incorporated elements that are based on scientific principles or concepts which could be applied in engineering fields [13]. MinecraftEdu is a software that combines entertainment and education, offering a multiplayer online gameplay where players can collaborate to complete construction tasks within the game.

The research aims to provide undergraduate construction engineering students with practical experience in practicing generic competencies such as collaboration and problem-solving relevant to their field. MinecraftEdu was identified as a potential tool to help students develop and practice these competencies during class after exploring various software options. The study also seeks to investigate the effectiveness of MinecraftEdu in enhancing college students' collaboration and problem-solving skills.

## Literature Review

Competency is generally defined as a combination of knowledge, skills, and attitudes [18]. This study focused on two key competencies; collaboration and problem-solving that are essential in

the field of construction engineering, both in academic and professional contexts [17], [19]. To succeed in today's world, construction professionals and graduates need a range of competencies. These include a strong technical foundation of construction skills, an awareness of ethical issues, good problem-solving skills, leadership abilities, an understanding of safety issues, and collaborative skills [23]. According to research, ethical issues, problem-solving skills, and interpersonal competencies such as collaboration were among the top competencies that employers sought when hiring new employees in the civil engineering and construction professions [21].

Construction engineering students require hands-on experience to improve these competencies necessary for their future careers. Although College graduates often overestimate their abilities, yet employers report a lack of basic soft skills, including communication, critical thinking, and problem-solving, among this group of potential job candidates [15]. A significant proportion of industry managers perceive the communication skills of engineering graduates to be inadequate [6]. Collaborative learning is a process where individuals work together to gain knowledge about a specific subject [16]. Collaborative learning can be an effective way to foster teamwork by emphasizing interpersonal and communication skills [16]. A study has suggested that civil and construction engineers perform a variety of roles, ranging from project managers to technical specialists, that necessitate not only fundamental technical expertise but also effective collaboration [17]. Active listening and effective communication skills are essential components of the collaboration competence [20].

The construction industry faces challenges including decreased productivity, workplace safety issues, and labor disputes despite being a significant contributor to the global economy. Problem-solving is another crucial competence for construction engineering students, entry-level engineers, and construction management to learn. Effective construction project management and problem-solving abilities are crucial in addressing many of these challenges faced by the construction industry [22]. Previous studies have highlighted that the term "leadership" in engineering field typically encompasses competencies such as problem-solving, communication, and teamwork [21]. There is a correlation between communication and problem-solving. Poor communication in engineering workplaces can negatively impact problem resolution and problem-solving efforts by causing misunderstandings, decreased efficiency, and wasted time [20].

Research suggests that a lecture-based approach is generally ineffective in developing critical thinking, communication, and leadership skills in engineering students [16]. According to Markopoulos et al. (2015), game characteristics such as achievements, levels, points, quests, status, and collaboration are applicable to engineering education and can enhance motivation, interest, and knowledge [12]. The use of Minecraft as an educational tool has become increasingly popular among educators worldwide for student projects, sharing, and learning [24]. A study suggested the use of Minecraft as a tool to enhance creativity by allowing students to create 3D constructions [25]. The study showed that using Minecraft as a substitute for CAD 3D software is a good idea. It eliminates the difficulty of learning the software and improves creativity in constructing 3D models [25]. MinecraftEdu is a school-level hybrid of Minecraft with educational and entertaining features. It includes modifications to make it more appropriate for the classroom, helping students develop various skills like teamwork skills [14]. Despite the

potential benefits of game-based learning, its implementation in engineering education, especially for the development of soft skills in construction engineering, remains relatively unexplored and under-researched.

## Methodology

### Game-based experimental learning

To enhance the development of construction engineering students' competencies in collaboration and problem-solving, an innovative educational game design was implemented using MinecraftEdu as a form of game-based education. The active learning methodology adopted aimed to assess the students' behavior and attitudes in exploring and practicing the competencies under study and their respective skills of active listening, communication, decision-making, and logical thinking, showing their ability to cooperate efficiently with their peers and tackle complex issues in a challenging environment. To put these competencies into practice, a group of five students from construction engineering program was tasked with constructing a one-story single-family home within specific requirements and a set timeframe. These requirements included a house with a total area of 1200 square feet, featuring a living room, dining room, kitchen, one bathroom, and one bedroom, with no specific design guidelines. To make the project more challenging, some difficulties and obstacles were introduced, such as accommodating the client's changing needs and requests. The game-based pilot study was conducted in a structured manner following some learning supports, such as printed instructions, demo, and instructors' guidance, to ensure students could understand and utilize MinecraftEdu software effectively. It is important to note that the students were not informed about the objective of the research, this allowed the study to observe the natural interaction between the students, without putting any pressure on them to consciously practice the targeted skills. To begin with, students were provided with printed instructions and a demo to assist them in downloading and installing the software, as well as an overview of the basics of how to play the game. Once students had grasped the basics, they were then given a comprehensive explanation of the task, including the specific requirements of the client. With a clear understanding of the task, the students commenced building a house in Minecraft, the task was given a set time of 80 minutes for the students to work on.

### Evaluation

To assess the effectiveness of the game-based learning approach, a two-level assessment strategy was implemented. The first level involved a checklist, which analyzed the students' behaviors and attitudes to determine whether they were exhibiting the required skills. This was done by observing their facial expressions and body movements and marking "yes" or "no" for each behavior. At least three specific behaviors were identified and evaluated for each skill (Table 1).

Table 1: Students' behavior Checklist

| Competency | Skills | Behaviors |
|---|---|---|
| Collaboration | Communication | The student demonstrates its opinion |
| | | The student asked questions |
| | | The topic of conversation was about the activity |

| | | |
|---|---|---|
| | | The student interacts with other members |
| | Active listening | The student didn't interrupt other members when they were talking |
| | | The student pays attention by nodding their head positively or saying "yes", "hum" |
| | | The student understood his/her task |
| | | The student was looking to the team member when he was talking |
| Problem Solving | Logical thinking | The student identified a problem |
| | | The student give solution to a problem |
| | | The student implements the solution to a problem |
| | Decision Making | The student was excited to achieve the goal |
| | | The student gives solutions to optimize the design |
| | | The student shared his/her point of view |

The second level of assessment involved a questionnaire that was divided into three sections, each using a 5-point Likert scale (strongly disagree, disagree, neutral, agree, and strongly agree). The first section of second level of assessment focused on measuring the students' attitudes, feelings, and self-assessments during the construction design process, to gauge how well they had performed the required skills. To avoid any bias, three attitudes were designed for each skill (Table 2).

Table 2: Students' attitude perception

| Skills Measured | Attitude |
|---|---|
| Measure the active listening | I learned from what the other students was saying |
| | I listened carefully and understood other students' questions, comments, and feedback |
| | I was able to reflect and judge what other students was saying |
| Measure the communication | I feel motivated to share information with the other student on my group |
| | I tried to be active in asking and talking to the students during the process |
| | The communication between students was clear |
| Measure Decision Making | I pointed possible alternatives to choose a solution |
| | Makes me feel like I need to make a decision to accomplish a goal |
| | Our group was fast in making decision |
| Measure Logical Thinking | I felt inspired to implement solutions after analyzing a problem |
| | I felt motivated to choose actions that give the best solutions |
| | It was easy for the group to come up with a solution |

The second section assessed the effectiveness of the learning supports, such as the printed instructions, instructors' guidance, and the demo, through feedback from the students (Table 3). It also used a 5-point Likert scale measurement (strongly disagree, disagree, neutral, agree, and strongly agree).

Table 3: Students' feedback on learning supports.

| | Learning Supports |
|---|---|
| To measure the Learning Supports | The verbal instructions helped me to understand the subject and the next steps |
| | The instructor/facilitator's guidance was comprehensive |
| | The Minecraft activities instructions was simple to understand |
| | The Minecraft installation instruction was straightforward to follow |
| | The demo was simple to understand |
| | The time distribution was adequate |

Finally, the last section aimed to measure the quality of MinecraftEdu as an educational tool, by gathering the students' perceptions of its usefulness (Table 4) by using a 5-point Likert scale (strongly disagree, disagree, neutral, agree, and strongly agree). The comprehensive assessment strategy enabled a thorough evaluation of the game-based learning approach and provided valuable insights into its effectiveness in promoting collaboration and problem-solving among construction engineering students.

Table 4: Students' perception on Minecraft tool

| | Minecraft Feedback |
|---|---|
| To measure the quality of Minecraft as an educational tool | It was simple to install the Minecraft |
| | It was simple to understand how to play Minecraft |
| | I believe Minecraft activity helps me to engage in classroom activities. |
| | I enjoyed using Minecraft in this class |
| | I like the game-based learning environment more than a lecture-based |
| | I am motivated to have game-based activities in other classes |

Results and discussions

Checklist

The results of the innovative educational activity were analyzed through a two-level assessment involving a checklist and a questionnaire. The checklist was used to verify the number of students that chose "yes" or "no" for each behavior related to the skills being taught. Based on this analysis, the students exhibited the following behaviors related to communication skills: All the students expressed their opinions, engaged in conversation related to the activity, and interacted with other members. However, only four students asked questions. In terms of active listening skills, all the students paid attention to their tasks, understood what was being said, and looked at the team member when they were talking. However, only four students did not refrain from interrupting other members when they were talking. In terms of logical thinking skills, all the students identified a problem, but only four students provided a solution and implemented it. Finally, all the students were motivated to achieve their goals and share their opinions regarding decision-making skills. However, only three students provided solutions to optimize the design (Figure 1).

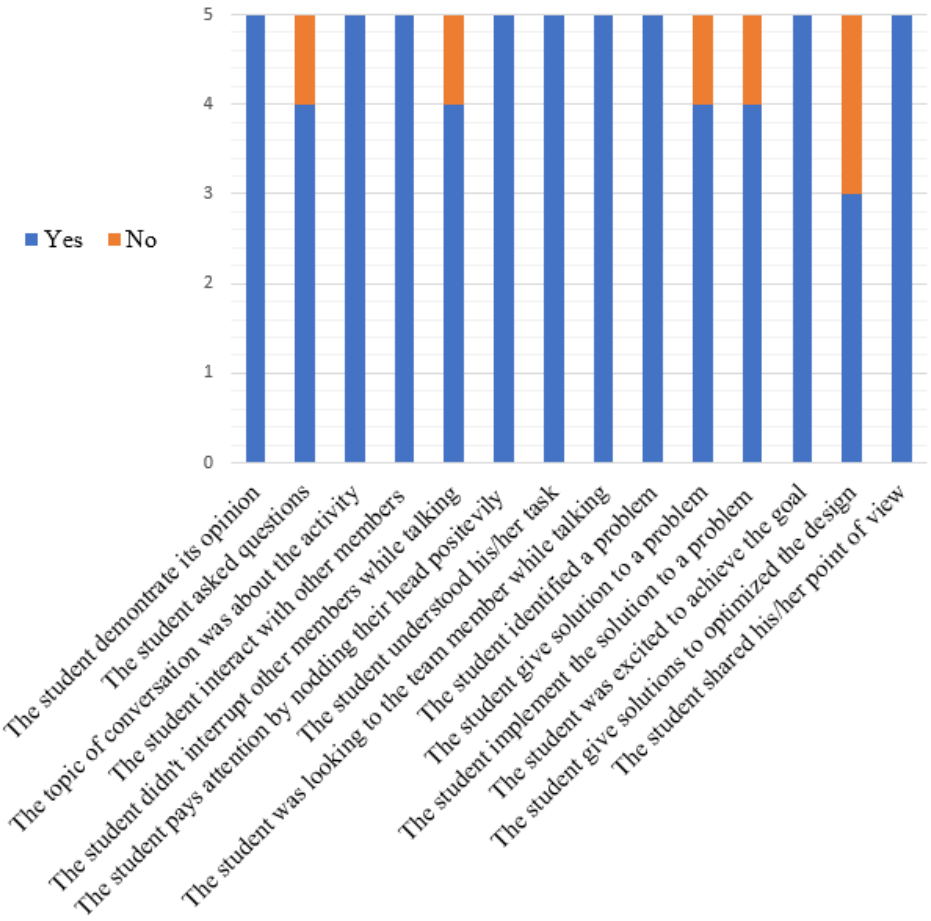


Figure 1: Checklist Results

From this study, it seems that the innovative educational activity using Minecraft has shown promising results in developing communication, active listening, logical thinking, and decision-making skills among construction engineering students. It is encouraging to note that all students demonstrated their opinions and interacted with other members mainly about planning the construction sequence, suggesting a good level of communication skills. Additionally, all students were paying attention, understanding their tasks, and looking at the team members when they were talking, which indicates that they acquired active listening skills. However, it is worth noting that some students did not interrupt others when they were talking, and only some students gave solutions to problems and even fewer implemented them indicating that there is room for improvement in terms of logical thinking and decision-making skills. Overall, the results suggest that Minecraft could be a useful tool for developing these skills in construction engineering students. It is important to emphasize that the challenges related to clients' requirements allowed students to communicate effectively. Moreover, the absence of a specific project design helped students to interact with each other and work collaboratively to find the best layout and materials to be used.

Questionnaire

Based on the results of the first section of the questionnaire, it was found that a large majority of students held a positive attitude toward the use of Minecraft as a learning tool. All the students strongly agreed that the game provided them with valuable opportunities to exercise their decision-making skills and improve their logical thinking abilities. Furthermore, most students strongly agreed that using Minecraft as an educational tool enhanced their ability to communicate effectively and encouraged them to be more patient when listening to others. It is noted that the students were not informed of the objective of the study while playing Minecraft, yet they were still able to acquire the desired skills. This indicates that the use of Minecraft as a learning tool has the potential to be a natural and effective method for skill development, as students were able to learn through engaging without necessarily being aware of the specific learning objectives (Figure 2).

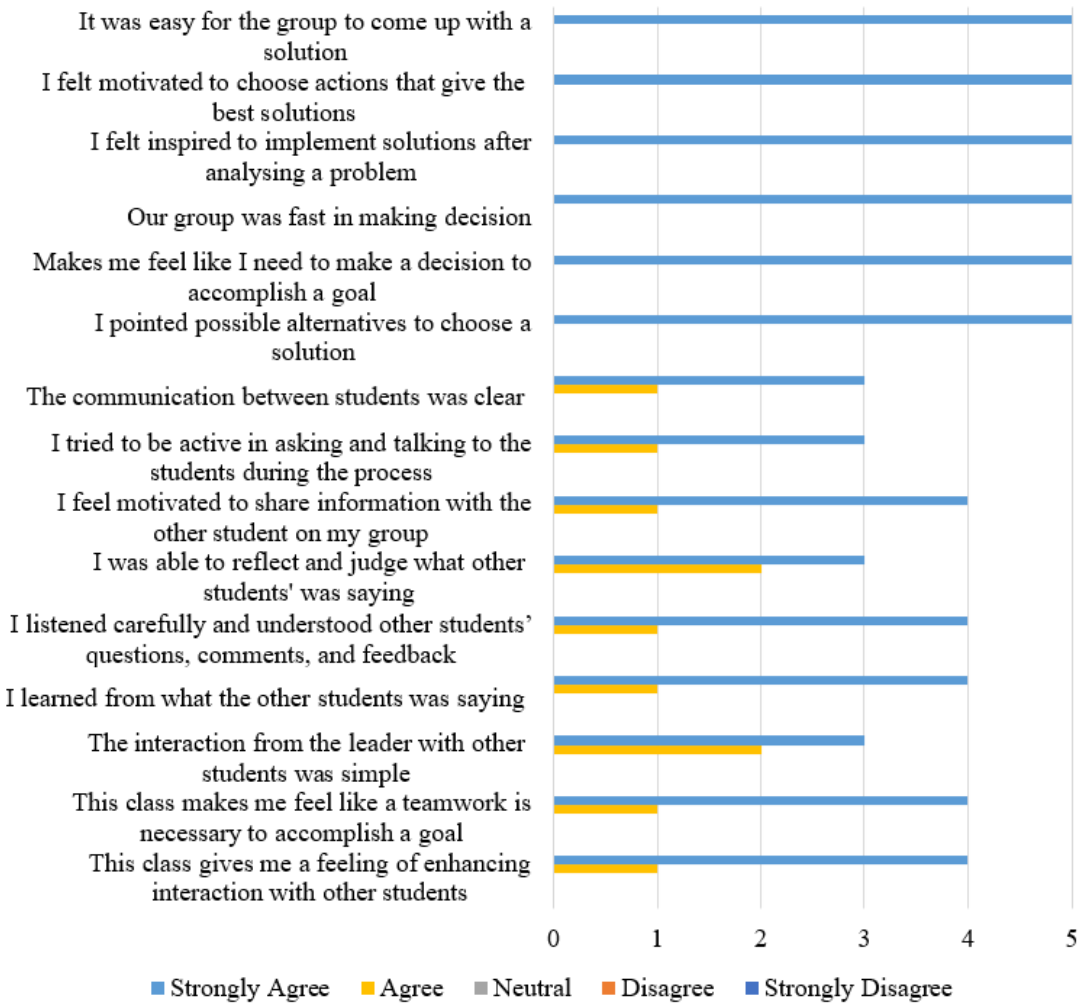


Figure 2: Questionnaire Results (Students' Self-Assessment)

The second section of this questionnaire measures the students' satisfaction on the class instruction, and most of the students agreed that the verbal instruction, instructor guidance, and

the demo were well presented and understandable (Figure 3). These findings suggest that the instructions were effective in communicating class content and providing guidance to the students.

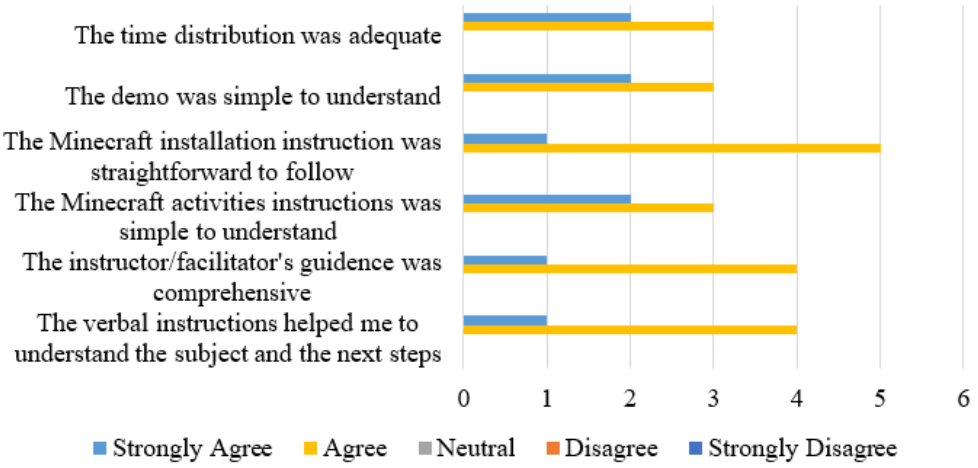


Figure 3: Questionnaire Results (Students' Pilot Study Feedback)

The last section measures the student's satisfaction on using Minecraft, it is worth noting that despite having no prior experience with Minecraft, students found the game to be both easy to play and highly enjoyable and were thus motivated to engage with it hands-on (Figure 4). This positive experience is reflected in the satisfaction ratings provided in the last section.

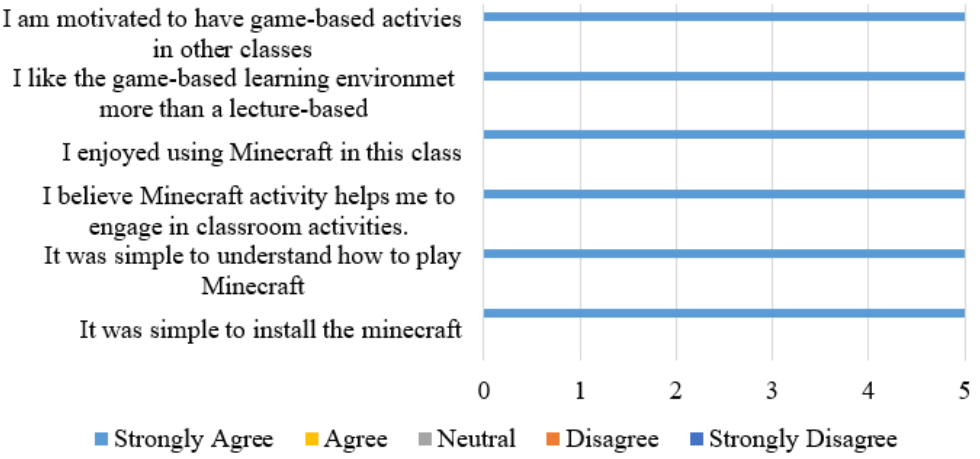


Figure 4: Questionnaire Results (Students' Minecraft Perception)

## Conclusion

The construction industry, being one that heavily relies on manual labor, places a high demand on social competencies and skills such as collaboration, communication, active listening, problem-solving, logic-thinking, and decision-making. However, students majoring in construction engineering often lack the opportunity to practice these competencies during their undergraduate education, which can pose significant challenges when entering the workforce after graduation. To address this issue, this research examines the potential of MinecraftEdu, a specialized software

application, to foster teamwork competencies among university students. The objective of this paper was to conduct pilot studies that required students to work in groups and build a one-story single-family home in Minecraft within a specified time frame. To make the project more challenging, obstacles such as accommodating the client's changing needs and requests were introduced, while ensuring that the house built had a minimum area of 1200 square feet. To assist in this endeavor, learning supports such as demo videos and printed instructions were provided to help students navigate Minecraft and complete the tasks. Through the two levels of assessment, the first level employed a checklist to assess whether students exhibited the necessary skills. The second level consisted of a questionnaire divided into three parts measuring students' feedback, attitudes, and self-assessment during the construction design process.

The results of this study suggest that the use of Minecraft as an innovative educational tool has the potential to develop communication, active listening, logical thinking, and decision-making skills among construction engineering students. The findings highlight the importance of effective communication and active listening skills in group work, as all students demonstrated their opinions, engaged in conversations related to the activity, and paid attention to their tasks. The use of Minecraft also provided opportunities for students to collaborate and work together to find the best solutions, however, there is still room for improvement in terms of logical thinking and decision-making skills, as only a few students provided solutions and implemented them. To address the limitations, the incorporation of more complex and diverse challenges within the Minecraft activity can be required to further develop logical thinking and decision-making skills. Future studies could focus on expanding the sample size and exploring different age groups or educational levels to assess the generalizability of the findings. Moreover, researchers could investigate the long-term effects of using Minecraft on the development and application of these skills in real-world contexts. Overall, these directions could help identify the most effective ways to utilize Minecraft as a tool for developing these skills in students and support the continuous improvement of educational practices in the field of construction engineering.

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