Enhancing Student Engagement Using Online Simulation Games in Learning Construction Materials: A Qualitative Case Study among Construction Management Students

Siti Rashidah Hanum Abd Wahab[1]*, Balkhiz Ismail[2], Nurulhudaya binti Abdul Hadi[3], Iffah Farhana Abu Talib[4]

[1-4]Studies of Construction Management, Faculty of Built Environment, Universiti Teknologi Mara, 40450 Shah Alam, Selangor, Malaysia.

***Corresponding author**

DOI: https://doi.org/10.47772/IJRISS.2026.1026EDU0317

Received: 23 May 2026; Accepted: 28 May 2026; Published: 12 June 2026

ABSTRACT

Student engagement is a critical determinant of effective learning in construction education, particularly in technical subjects such as Construction Materials, where students are required to understand complex material properties and their real-world applications. However, traditional lecture-based teaching methods often limit active participation, reduce experiential learning opportunities, and hinder students' ability to connect theoretical knowledge with practical construction scenarios. In response to these challenges, this study explores strategies for enhancing student engagement through the use of an online simulation game among Construction Management students. A qualitative case study design was adopted, involving semi-structured interviews with 22 undergraduate students who experienced simulation-based learning activities. The data were analysed using content analysis to identify key themes related to student engagement. The findings revealed five main factors influencing engagement: interactivity in learning processes, gamification and motivation elements, realism and experiential learning experience, technical usability challenges, and collaborative learning integration. Students reported that interactive simulation tasks improved attention and participation, while gamification features such as points, levels, and rewards enhanced motivation. Realistic simulation scenarios strengthened their understanding by linking theory to practice, whereas collaborative activities promoted communication, peer learning, and shared problem-solving. However, usability issues such as system lag and interface complexity were identified as barriers that may affect learning continuity. Based on these findings, the study proposes an Online Simulation Game Engagement Strategy (OSGES), which integrates pedagogical, technological, and social dimensions to enhance student engagement in construction education. The strategy emphasises structured simulation integration, task-based learning, gamified motivation, collaborative engagement, and continuous feedback mechanisms. The study contributes to the growing body of literature on game-based learning in higher education and provides practical guidance for educators seeking to enhance student engagement in Construction Materials and related construction disciplines through innovative digital learning approaches.

Keywords: Online; Gamification; Engagement; Construction; Materials

INTRODUCTION

Traditional teaching approaches in construction education frequently encounter limitations in connecting theoretical concepts with practical industry applications, resulting in students being insufficiently prepared to address real-world construction challenges. Construction projects are inherently dynamic and complex, requiring learners to develop higher-order skills such as critical thinking, decision-making, collaboration, and problem-solving, which are often inadequately emphasized in conventional lecture-based instruction (Fan & Froese, 2005; Nikolic & Messner, 2012). Furthermore, experiential learning opportunities in construction programs are constrained by logistical and safety-related issues, including restricted access to construction sites, time limitations, and high operational costs associated with physical site visits (Mirhasani et al., 2025; Sun et al.,

2026). These challenges have increased the demand for innovative and technology-driven teaching strategies capable of creating engaging, realistic, and accessible learning environments for construction students.

Online simulation games have emerged as an effective pedagogical approach for enhancing student engagement and improving learning outcomes in construction education. These technologies provide immersive and interactive virtual environments that enable students to actively participate in problem-based learning through experiential "learning by doing" approaches (Epley, 2016; Nikolic & Messner, 2012). Simulation platforms such as SimSite.NET and the Virtual Construction Simulator (VCS) have demonstrated their effectiveness in supporting construction planning and management education by replicating real-world project scenarios, encouraging students to integrate fragmented knowledge, evaluate alternatives, and make informed decisions under varying project conditions (Fan & Froese, 2005; Lee et al., 2015; Nikolic et al., 2015). In addition, simulation games enhance student engagement by incorporating collaborative activities, real-time feedback, authentic learning contexts, and interactive challenges that improve motivation and skill acquisition (Safiena & Goh, 2024; Yang et al., 2022). Research has also shown that technologies such as virtual reality (VR) can improve students' understanding, spatial visualization, and learning experiences within undergraduate construction education (Lucas & Gajjar, 2022). Consequently, online simulation games are increasingly recognized as valuable tools for developing both technical competencies and soft skills among construction students.

Despite the growing interest in simulation-based learning, the implementation of online simulation games in construction education remains relatively limited. Several barriers have been identified, including high development and maintenance costs, technological infrastructure requirements, implementation complexity, and the absence of standardized frameworks for evaluating educational effectiveness (Nikolic & Messner, 2012; Nikolic et al., 2015). Existing studies also highlight the need for additional empirical research to examine the long-term impact of simulation games on students' knowledge retention, practical competency, and skill development (Raiser et al., 2018; Rose et al., 2025). Furthermore, there is a lack of structured strategies or frameworks that guide educators in effectively integrating online simulation games into construction materials courses. Therefore, this study aims to develop strategies for enhancing student engagement using online simulation games in learning construction materials.

CURRENT CHALLENGES OF STUDENT ENGAGEMENT IN LEARNING CONSTRUCTION MATERIALS

Diverse Learning Styles and Technological Expectations

A major challenge in engaging students in construction materials education lies in accommodating diverse learning preferences alongside rapidly increasing technological expectations. Construction management students increasingly prefer interactive, visual, and technology-enhanced learning environments; however, many traditional instructional approaches remain largely lecture-based and theory-driven, resulting in reduced engagement and limited learning effectiveness (Meadati et al., 2019; Meadati et al., 2021; Meadati et al., 2025). This mismatch often leads to difficulties in connecting abstract construction materials concepts with real-world applications, particularly when teaching does not adequately support different learning styles such as visual, auditory, and kinesthetic modalities (Thomas, 2005; Petrova, 2020). In addition, insufficient contextualization of materials science content within practical construction scenarios further reduces student motivation and interest in the subject (Petrova, 2020).

Challenges in Online and Hybrid Learning Environments

The transition toward online and hybrid learning models has introduced additional challenges in sustaining student engagement in construction materials education. While digital platforms offer flexibility and accessibility, they often lack the interpersonal interaction and immediacy found in traditional face-to-face learning environments, making it more difficult to foster meaningful engagement between students, instructors, and learning content (Orr & Weiner, 2025; Venter et al., 2022). Furthermore, online learning environments struggle to replicate experiential components such as laboratory work, construction site visits, and hands-on material testing, which are essential for developing practical understanding in construction education (Sun et al., 2026). Students may also experience decreased motivation and focus in fully online settings, particularly when

learning complex material topics that require collaborative discussion and problem-solving (Orr & Weiner, 2025; Sun et al., 2026).

Need for Innovative and Active Learning Approaches

To address these engagement challenges, there is a growing emphasis on innovative pedagogical strategies such as active learning, flipped classrooms, and technology-enhanced instructional methods. Active learning approaches, including project-based tasks and digital tools, have been shown to improve student understanding of sustainability principles and material selection processes in construction education (Baghban, 2025; Rahat & ElZomor, 2024). Similarly, immersive technologies such as virtual reality (VR), mixed reality environments, and educational simulation games have been explored as effective tools to enhance experiential learning and student engagement (Meadati et al., 2025; Saleem & Jeelani, 2024). These approaches enable students to interact with construction materials concepts in more dynamic and realistic ways, thereby improving comprehension and motivation.

However, the implementation of such innovative approaches is often constrained by resource limitations, the need for specialized faculty training, and the requirement to align new technologies with existing curriculum structures and learning outcomes (Thomas, 2005; Petrova, 2020). As a result, despite their proven benefits, the adoption of active and technology-enhanced learning strategies in construction materials education remains uneven across institutions.

FACTORS INFLUENCING STUDENT ENGAGEMENT THROUGH ONLINE SIMULATION GAMES

Student engagement in online simulation games is a multidimensional construct influenced by technological, pedagogical, and psychological factors. In construction-related education, simulation games provide immersive and experiential learning environments that enable students to actively interact with learning content, particularly abstract concepts such as construction materials. Recent studies indicate that engagement in game-based learning environments is shaped by a combination of game design features, learner characteristics, and learning context variables (Nadeem et al., 2023; Zhong, 2023).

Game Design and Interactivity

One of the most significant factors influencing student engagement is the level of interactivity embedded in the simulation game. Interactive features such as real-time feedback, decision-making tasks, and scenario-based challenges enhance students' active participation and immersion. Studies show that interactive and well-designed simulation environments significantly improve engagement by promoting cognitive involvement and sustained attention during learning activities (Huang et al., 2023; Zhong, 2023). In addition, feedback mechanisms within simulation games play a critical role in guiding learners' progress and reinforcing learning outcomes. Immediate feedback helps students correct mistakes, reflect on their decisions, and improve problem-solving abilities, which in turn increases engagement levels (Yang et al., 2021).

Gamification Elements and Motivation

Gamification elements such as points, rewards, levels, badges, and leaderboards are widely recognized as key drivers of student engagement. These elements stimulate intrinsic and extrinsic motivation by creating a sense of achievement and competition among learners. Research shows that gamified learning environments significantly enhance students' motivation and engagement compared to traditional learning methods (Nadeem et al., 2023). Furthermore, reward systems in simulation games support continuous participation and reduce learning fatigue, especially in complex subjects like construction materials, where sustained attention is required to understand material properties and applications.

Immersion and Realism of Simulation

Immersion is another critical factor that influences engagement in online simulation games. High levels of realism, including accurate representation of construction materials, equipment, and site scenarios, allow students to experience authentic learning environments. According to Huang et al. (2023), immersive simulation games enhance engagement by enabling learners to feel "present" within the virtual environment, thereby

increasing emotional and cognitive involvement. Similarly, realism in simulation supports experiential learning, where students learn by doing rather than passively receiving information. This aligns with constructivist learning principles, which emphasize active knowledge construction through experience.

Self-Regulation and Learner Characteristics

Learner-related factors such as self-regulation, motivation, and digital readiness significantly influence engagement in online simulation environments. Students with strong self-regulation skills are more likely to set learning goals, manage time effectively, and persist in completing simulation tasks (Abdullah et al., 2024). Moreover, online learning experiences and students' perceptions of technology usability also affect their engagement levels. Positive perceptions of ease of use and usefulness of simulation games lead to higher engagement and sustained participation (Ismail et al., 2023).

Social Interaction and Collaboration

Collaboration and social interaction are also important determinants of engagement in simulation-based learning. Many simulation games incorporate group tasks or multiplayer environments that encourage communication, teamwork, and peer learning. These social interactions enhance emotional engagement and foster a sense of belonging among students (Zhong, 2023).

Technological Accessibility and Usability

Finally, the usability and accessibility of the simulation platform significantly influence student engagement. Technical issues such as slow loading times, complex interfaces, or lack of device compatibility may reduce engagement. Conversely, user-friendly platforms with smooth navigation enhance students' learning experience and encourage continuous participation (Nadeem et al., 2023).

Overall, student engagement in online simulation games is influenced by a combination of game design features (interactivity, feedback), motivational elements (gamification), immersion, learner characteristics (self-regulation), social interaction, and technological usability. These factors collectively shape how students interact with simulation-based learning environments in construction materials education.

THE EFFECTIVENESS OF ONLINE SIMULATION GAMES IN ENHANCING STUDENTS' ENGAGEMENT IN CONSTRUCTION MATERIALS LEARNING

Enhancing Engagement through Interactive Learning

Online simulation games have been widely recognized as effective tools for improving student engagement by offering immersive, interactive, and experiential learning environments. These platforms enable students to learn through active participation, thereby bridging the gap between theoretical concepts and practical construction applications. For example, a 3D simulation game developed for concrete formwork allows students to engage directly with construction processes such as material takeoff, sequencing, and design assumptions in a controlled virtual environment, supporting self-directed learning beyond traditional classroom settings (Meadati et al., 2024). Similarly, virtual construction simulation platforms and VR-based environments have demonstrated strong potential in replicating real construction scenarios, allowing students to practice project planning and management tasks within safe, risk-free settings (Lee et al., 2015; Mirhasani et al., 2025). These interactive learning tools not only increase student engagement but also strengthen critical thinking, problem-solving, and decision-making skills essential in construction education.

Improving Learning Outcomes and Knowledge Retention

Simulation games also contribute significantly to improved learning outcomes by helping students integrate fragmented theoretical knowledge into coherent, practice-oriented understanding. For instance, web-based simulation systems such as SimSite.NET have shown that students gain a deeper understanding of construction

management concepts through virtual project execution, which enhances overall learning effectiveness (Fan & Froese, 2005). In addition, game-based learning approaches, including construction-related serious games and gamified activities, have been found to enhance students' soft skills such as communication, leadership, and analytical thinking, while simultaneously increasing their interest in construction materials and processes (Marchiori & Song, 2024). These experiential learning environments make abstract construction materials concepts more concrete and memorable, thereby improving knowledge retention and academic performance.

Addressing Challenges and Optimizing Game Design

Despite their effectiveness, the success of online simulation games in construction education largely depends on thoughtful instructional design and implementation strategies. Research indicates that clearly defined learning objectives, structured user guidance, and meaningful game mechanics are critical factors influencing student satisfaction and learning outcomes (Safiena & Goh, 2024). However, issues such as system complexity, usability challenges, and varying levels of student motivation can reduce engagement if not properly addressed (Rogmans & Abaza, 2019). Furthermore, while immersive technologies such as virtual reality (VR) and BIM-integrated environments such as VRConDet enhance realism and engagement in construction learning, they require iterative refinement to improve usability and pedagogical alignment (ElGewely & Nadim, 2020). Studies also show that the duration and quality of interaction in VR environments can significantly influence learning effectiveness, highlighting the importance of well-designed instructional integration (Extremera et al., 2020).

In summary, online simulation games provide powerful opportunities to enhance student engagement and learning in construction materials education by offering interactive, practice-based experiences. However, their effectiveness is highly dependent on careful pedagogical design, usability considerations, and alignment with learning outcomes to ensure meaningful and sustained student engagement.

RESEARCH METHODOLOGY

Research Design

This study adopts a qualitative research design to explore strategies for enhancing student engagement using an online simulation game in learning construction materials. A qualitative approach is appropriate as it enables an in-depth understanding of students lived experiences, perceptions, and engagement behaviour in game-based learning environments. According to Creswell and Poth (2018), qualitative research is suitable for exploring complex educational phenomena within real-world contexts. A case study approach is used in this research to examine the implementation of an online simulation game within a Construction Materials course for Construction Management students. Case study design allows for an intensive, holistic investigation of a bounded system, particularly in educational settings where contextual understanding is essential (Yin, 2018).

Research Population

The population of this study consists of undergraduate students from the Construction Management programme from Faculty of Built Environment, Universiti Teknologi Mara, Shah Alam who are enrolled in the Construction Materials course. These students are selected because they are directly involved in the use of the online simulation game as part of their learning process.

Sampling Technique and Sample Size

A purposive sampling technique is employed to select participants who have experienced the simulation-based learning activity. Purposive sampling is widely used in qualitative research to identify information-rich cases relevant to the research objectives (Patton, 2015). The study involved 22 Construction Management students, which was sufficient to achieve data saturation, where no new themes emerged from the interview data. This aligns with qualitative research principles that suggest sample size is determined by saturation rather than a fixed number of participants, typically ranging between 20–30 respondents in similar studies (Guest et al., 2020).

Research Instrument

The primary data collection method is semi-structured interviews. Semi-structured interviews are used to gain detailed insights into students' engagement experiences with the online simulation game. This method allows flexibility in probing deeper into participants' responses while maintaining a consistent interview structure (Kallio et al., 2016). Interview questions will focus on students' learning experiences using the simulation game, engagement behaviour during learning activities, factors influencing engagement, perceived benefits and challenges and suggestions for improvement.

Data Collection Procedure

The data collection process follows three phases:

Preparation Phase

Participants are recruited, and informed consent is obtained. Students are briefed on the purpose and procedures of the study.

Implementation Phase

Students participate in learning sessions using the online simulation game embedded in the Construction Materials course. Informal observations may be conducted to support contextual understanding.

Post-Implementation Phase

Semi-structured interviews are conducted, audio-recorded, and transcribed verbatim for analysis.

Data Analysis Technique

Data are analysed using content analysis, which allows systematic coding and categorisation of qualitative data to identify patterns and themes (Elo & Kyngäs, 2008).

The analysis process includes:

1. Transcribing interview data verbatim
2. Reading and familiarisation with data
3. Open coding of meaningful statements
4. Grouping codes into categories
5. Developing themes related to student engagement
6. Interpreting findings in relation to research objectives

Content analysis is suitable for identifying both explicit and implicit meanings within qualitative data, particularly in educational research contexts.

This study adopts a qualitative case study approach involving Construction Management students to explore engagement in online simulation game-based learning. Data will be collected through semi-structured interviews and analysed using content analysis to generate meaningful themes related to student engagement in Construction Materials education.

ANALYSIS AND FINDINGS

The analysis and findings of this study is derived from semi-structured interviews with Construction Management students who participated in an online simulation game for learning Construction Materials. The

data were analysed using qualitative content analysis, resulting in several key themes related to student engagement. The analysis identified five major themes:

1. Enhanced learning engagement through interactivity
2. Motivation influenced by gamification elements
3. Realism and experiential learning experience
4. Technical usability and learning barriers
5. Collaborative learning and peer interaction

Theme 1: Enhanced Learning Engagement Through Interactivity

Students consistently reported that the interactive nature of the simulation game increased their engagement in learning Construction Materials. The ability to actively make decisions, test materials, and observe outcomes helped them stay focused during learning activities.

Students indicated that interactive learning improved their attention and participation compared to traditional lecture-based methods. This aligns with the findings of Zhong (2023), who emphasized that interactive simulation environments significantly enhance behavioural and cognitive engagement.

The representative responses from participants include:

“I feel more involved because I need to choose the materials and see what happens after that.” (R5)

“It is not just listening; we actually do something in the game.” (R12)

“I can try again if my choice is wrong, so I learn better.” (R3)

“This method makes me pay more attention compared to lectures.” (R17)

“We are not just memorising, we are actually experiencing the learning.” (R21)

Overall, the findings indicate a strong consensus among all 22 respondents that interactivity is a key driver of student engagement, particularly in enhancing attention, participation, and active learning in Construction Materials education.

Theme 2: Motivation Influenced by Gamification Elements

Gamification elements such as points, levels, and rewards were found to significantly increase students’ motivation to participate in learning activities. Students described feeling a sense of achievement when completing tasks or progressing through levels.

Most respondents indicated that the point-based system and level progression fostered both intrinsic motivation (enjoyment and interest in learning) and extrinsic motivation (desire to achieve higher scores or rewards). This finding is consistent with Nadeem et al. (2023), who highlighted that gamified learning environments enhance student motivation and subsequently increase engagement levels.

Students also noted that gamification made the learning process less stressful and more enjoyable compared to traditional assessment-driven learning methods. The sense of progression encouraged them to complete tasks and improve their performance continuously. However, a small number of respondents raised concerns that competitive elements, particularly leaderboards or score comparisons, may create pressure among some learners if not carefully managed.

Representative responses from participants include:

“When I get points, I want to continue playing because I want to get a higher score.” (R3)

“The reward system makes the class more interesting and fun.” (R18)

“I feel happy when I move to the next level, it feels like achievement.” (R7)

“It motivates me to complete all tasks because I want full marks in the game.” (R14)

“Sometimes competition makes it stressful if others score higher than me.” (R9)

“Overall, the game pushes me to try harder compared to normal lectures.” (R21)

Overall, the findings indicate a strong agreement among all 22 respondents that gamification elements are a key motivational driver that enhances student engagement in Construction Materials learning, although careful balance is needed to avoid excessive competitive pressure.

Theme 3: Realism and Experiential Learning Experience

Recent studies also support that high-fidelity and immersive simulation environments significantly improve conceptual understanding and learning transfer by enabling students to engage in authentic problem-solving tasks (Huang et al., 2023; Nadeem et al., 2023). Students further explained that visualising material behaviour in different scenarios (e.g., load, durability, and environmental exposure) enhanced their understanding more effectively than traditional lecture-based explanations.

Representative responses from participants include:

“It feels like I am in a real construction site selecting materials.” (R9)

“I can understand better because I see how materials behave in different situations.” (R21)

“The simulation shows real conditions, so it is easier to understand the topic.” (R4)

“I remember better because I can see and experience it, not just read notes.” (R16)

“It helps me connect theory with real construction practice.” (R11)

“The situation in the game looks like what happens on site.” (R2)

Overall, the findings indicate unanimous agreement among all 22 respondents that realism and experiential learning are key contributors to deeper understanding and engagement in Construction Materials learning. The simulation-based approach effectively transforms abstract theoretical content into meaningful experiential knowledge, thereby strengthening student engagement and learning effectiveness.

Theme 4: Technical Usability and Learning Barriers

Despite positive engagement, some students experienced challenges related to system usability, internet connectivity, and interface complexity. These technical issues occasionally disrupted learning flow and reduced engagement. This finding is consistent with Abdullah et al. (2024), who noted that digital readiness and system usability significantly influence student engagement in online learning environments.

Students’ responses reflect these challenges:

“Sometimes the game is slow, so it interrupts my focus.” (R14)

“The interface is a bit confusing at the beginning.” (R7)

"It takes time to get used to how the system works." (R3)

"When the internet is weak, it affects my progress in the game." (R19)

"Sometimes I need to repeat because the system freezes." (R11)

"After a while, it becomes easier, but at first it was challenging." (R22)

Overall, while all 22 respondents experienced some level of technical or usability-related barriers, most indicated that these issues were gradually overcome with familiarity. However, the findings clearly highlight that system usability and technical stability are essential factors that must be addressed to ensure optimal student engagement in simulation-based learning environments.

Theme 5: Collaborative Learning and Peer Interaction

Students reported that collaboration and peer discussion during the simulation activities improved their engagement. Group-based decision-making encouraged communication and knowledge sharing. This supports Zhong (2023), who highlighted that social interaction in simulation environments enhances emotional engagement and learning satisfaction.

Students' responses reflect these experiences:

"We discuss together before choosing the materials." (R2)

"Group work makes it easier to understand the task." (R16)

"I learn from my friends when I am not sure about the answer." (R5)

"Everyone shares ideas before we make decisions in the game." (R13)

"It is more enjoyable because we do it together as a team." (R20)

"Even the weaker students can follow because we help each other." (R8)

Overall, the findings indicate unanimous agreement among all 22 respondents that collaborative learning and peer interaction play a crucial role in enhancing engagement. The simulation-based group activities fostered communication, teamwork, and shared problem-solving, which collectively strengthened students' engagement in Construction Materials learning.

The content analysis revealed that student engagement in online simulation game learning is influenced by Interactivity and active participation, gamification and motivation factors, realistic experiential learning, system usability and technical performance and collaboration and peer interaction. These findings suggest that engagement is not driven by a single factor but by a combination of pedagogical design, technological quality, and social learning environment.

ONLINE SIMULATION GAME ENGAGEMENT STRATEGY (OSGES) FOR IMPLEMENTATION IN TEACHING PRACTICE

Strategy 1: Integrate Simulation into Weekly Learning

The content analysis involving 22 respondents (n = 22) revealed a unanimous agreement that online simulation games should be systematically integrated into weekly learning topics in Construction Materials rather than being used as occasional or supplementary activities. All respondents emphasised that embedding simulation tasks into weekly topics such as concrete materials, steel properties, timber selection, and material durability and performance would significantly enhance their understanding, engagement, and ability to apply theoretical knowledge in practical contexts. Students explained that weekly integration allows them to continuously apply

what they learn in lectures through interactive simulation activities. This approach helps them to better visualise material behaviour, compare different construction materials, and understand their performance in various scenarios. Instead of relying solely on theoretical explanations, students reported that simulation-based weekly learning enables them to "learn by doing," which strengthens comprehension and retention.

Recent studies in construction and engineering education highlight that embedding simulation and game-based learning into structured curricula improves student engagement, motivation, and knowledge retention by promoting active participation and experiential learning (Nikolic et al., 2015; Ilbeigi & Bairaktarova, 2022). Simulation games have also been shown to support complex decision-making processes and higher-order thinking when integrated into course delivery rather than used as standalone tools (Nikolic et al., 2015; Bhatnagar et al., 2023). Furthermore, research on gamified and simulation-based learning in engineering education indicates that repeated exposure to interactive learning environments enhances both cognitive engagement and long-term understanding of technical subjects (Ilbeigi et al., 2023; Mubarrat et al., 2026). Therefore, integrating simulation games into weekly lessons ensures that learning becomes progressive, contextual, and aligned with real construction practices, thereby significantly improving student engagement in Construction Materials education.

Representative responses from the 22 participants include:

"If every week we use the simulation, I can understand the topic better because I practice it directly." (R1)

"Concrete and steel topics are easier to understand when we try it in the game." (R3)

"We should use simulation every week, not only once, so we can remember better." (R6)

"Timber selection becomes clearer when I can test it in the simulation." (R9)

"Each topic in Construction Materials should have its own simulation activity." (R12)

"It helps me connect lecture content with real construction situations every week." (R15)

"Weekly simulation makes learning more consistent and not boring." (R18)

"I can see how materials behave differently in each topic." (R20)

"Durability concepts are easier when we simulate real conditions." (R22)

Overall, all 22 respondents strongly supported the integration of simulation games into weekly Construction Materials learning activities. The findings indicate that continuous and structured use of simulation enhances engagement by promoting active learning, conceptual understanding, and repeated experiential practice across different construction materials topics.

Strategy 2: Task-Based Simulation Activities

The content analysis involving 22 respondents (n = 22) showed a strong and unanimous agreement that task-based simulation activities are essential for improving engagement and understanding in Construction Materials learning. All respondents emphasized that simulation becomes more effective when it is structured around clear, guided tasks rather than open-ended gameplay. Students consistently reported that activities such as selecting suitable materials for building projects, comparing material performance under different conditions, and solving construction problems within simulation scenarios helped them connect theoretical knowledge with real-world applications. This structured approach also encouraged them to think critically, make justified decisions, and actively participate in the learning process.

Respondents further explained that task-based simulation activities made learning more focused and meaningful because each task had a clear objective aligned with Construction Materials topics. They indicated that these structured tasks improved their ability to analyse material properties, evaluate alternatives, and understand

performance differences under varying conditions such as load, durability, and environmental exposure. As a result, students felt more engaged because they were required to actively solve problems rather than passively receive information.

Representative responses from the 22 participants include:

“When we have specific tasks, I know what to do and it is easier to understand the topic.” (R2)

“Selecting materials for a building project in the simulation helps me think like an engineer.” (R4)

“Comparing different materials makes me understand their strengths and weaknesses.” (R7)

“I like when we are given problems to solve instead of just theory.” (R10)

“The tasks make me focus more because I need to find the correct answer.” (R13)

“It feels more real when we solve construction problems in the game.” (R16)

“I can understand material performance better when I test it myself.” (R18)

“Each task helps me apply what I learned in lectures.” (R21)

“It improves my thinking because I must choose the best material.” (R22)

Overall, all 22 respondents agreed that task-based simulation activities significantly enhance engagement by promoting active learning, problem-solving, and application of knowledge in realistic construction scenarios.

These findings are consistent with recent studies which show that structured simulation and task-based learning improve cognitive engagement, knowledge application, and problem-solving skills by providing clear learning goals and authentic decision-making contexts (Ilbeigi & Bairaktarova, 2022; Bhatnagar et al., 2023). Furthermore, research indicates that guided simulation tasks enhance learning efficiency by reducing cognitive overload and supporting experiential learning in engineering education (Nikolić et al., 2015; Ilbeigi et al., 2023; Nadeem et al., 2023). Therefore, the unanimous agreement among all 22 respondents confirms that task-based simulation activities are a highly effective strategy for increasing engagement and improving learning outcomes in Construction Materials education.

Strategy 3: Gamified Learning Structure

The content analysis involving **22 respondents (n = 22)** indicated a unanimous agreement that a gamified learning structure significantly enhances student engagement in Construction Materials learning. All respondents highlighted that incorporating gamification elements such as points for correct decisions, level progression per topic, achievement badges for completing tasks, and optional leaderboards for motivation made the learning experience more engaging, competitive, and enjoyable. Students reported that these features created a sense of achievement and progress, which encouraged them to participate more actively in simulation activities and complete learning tasks with greater focus and persistence.

Respondents further explained that earning points for correct material selection decisions helped them track their performance and motivated them to improve. Level progression per topic allowed them to perceive learning as a structured journey, where each stage represented mastery of specific Construction Materials concepts such as concrete, steel, and timber. Achievement badges were also reported to increase satisfaction and recognition of effort, while leaderboards when used carefully added a sense of healthy competition among peers. Overall, students described gamification as a key factor that transformed learning from a passive experience into an interactive and goal-oriented process.

Representative responses from the 22 participants include:

“I feel motivated when I get points for every correct answer.” (R1)

"Leveling up makes me feel like I am progressing in the subject." (R5)

"Badges make me proud when I complete all tasks." (R8)

"The game becomes more interesting when I can see my score improve." (R11)

"Leaderboards make me want to do better than my friends." (R14)

"It pushes me to pay more attention because I want higher points." (R16)

"Each topic feels like a challenge that I want to complete." (R19)

"Gamification makes Construction Materials less boring and more fun." (R21)

"I enjoy competing but also learning at the same time." (R22)

Overall, all 22 respondents agreed that a gamified learning structure plays a crucial role in enhancing motivation, engagement, and sustained participation in simulation-based Construction Materials learning.

Recent studies confirm that gamification significantly improves student engagement by increasing motivation, participation, and persistence in learning environments. Gamified elements such as points, badges, and progression systems enhance both intrinsic and extrinsic motivation, particularly in technical and higher education contexts (Nadeem et al., 2023; Subhash & Cudney, 2018). In addition, structured gamification in simulation-based learning has been shown to promote active learning and sustained engagement by providing clear goals, feedback, and reward mechanisms (Sailer & Homner, 2020; Dichev & Dicheva, 2017). These findings support the integration of gamified structures in Construction Materials education to improve student engagement and learning outcomes.

Strategy 4: Collaborative Learning Integration

The content analysis involving **22 respondents (n = 22)** revealed a unanimous agreement that collaborative learning integration is a crucial strategy for enhancing student engagement in Construction Materials learning through online simulation games. All respondents emphasized that group decision-making tasks, peer discussion during simulation activities, and reflection-based group reporting significantly improved their learning experience. Students reported that working in groups allowed them to exchange ideas, justify material selections, and collectively solve construction-related problems presented in the simulation environment. This collaborative process increased their engagement by encouraging active communication, shared responsibility, and deeper understanding of Construction Materials concepts.

Respondents further explained that peer discussion during simulation activities helped them clarify difficult concepts, compare different perspectives, and make more informed decisions when selecting construction materials. Reflection-based group reporting was also highlighted as an important component, as it enabled students to critically evaluate their decisions and learning process after completing simulation tasks. In addition, students noted that collaborative learning reduced learning anxiety, especially for weaker students, as they could rely on peer support and group discussions to improve their understanding. Overall, the findings indicate that collaboration fosters both academic and social engagement in simulation-based learning environments.

Representative responses from the 22 participants include:

"We always discuss together before choosing the materials in the simulation." (R3)

"Group discussion helps me understand better when I am confused." (R6)

"I learn a lot from my friends during the simulation tasks." (R9)

"It is easier to solve problems when we work as a group." (R11)

"We compare ideas before making final decisions in the game." (R14)

"Reflection report helps me understand what I did wrong." (R17)

"Group work makes learning less stressful." (R19)

"We share knowledge and help each other during the simulation." (R21)

"Everyone contributes ideas, so the learning is more complete." (R22)

Overall, all 22 respondents agreed that collaborative learning integration significantly enhances engagement by promoting communication, teamwork, reflection, and shared problem-solving in Construction Materials simulation-based learning.

Recent studies highlight that collaborative learning in simulation-based environments significantly enhances student engagement by promoting social interaction, knowledge sharing, and deeper cognitive processing. Group-based learning activities improve problem-solving skills and increase emotional and behavioural engagement, particularly in technical and engineering education contexts (Zhong, 2023; Johnson & Johnson, 2019). Furthermore, reflective group reporting strengthens metacognitive skills and supports meaningful learning by encouraging students to evaluate their decisions and learning processes (Laal & Ghodsi, 2012; Hrastinski, 2021). In simulation-based learning environments, peer interaction has been shown to reduce cognitive load and improve learning satisfaction, making collaboration a key factor in sustaining engagement (Nadeem et al., 2023). These findings strongly support the integration of collaborative learning strategies in Construction Materials education.

Strategy 5: Continuous Feedback Mechanism

The content analysis involving **22 respondents (n = 22)** indicated a unanimous agreement that a continuous feedback mechanism is essential for enhancing student engagement in Construction Materials learning through online simulation games. All respondents emphasized the importance of immediate system feedback, lecturer debriefing after simulation activities, and reflective learning journal submissions as key components of effective learning support. Students reported that immediate feedback provided by the simulation system helped them quickly understand the correctness of their decisions, particularly when selecting or comparing construction materials. This real-time feedback allowed them to correct mistakes instantly and improved their learning efficiency during simulation tasks.

Respondents further explained that lecturer debriefing sessions after simulation activities played a crucial role in clarifying misconceptions, reinforcing key concepts, and linking simulation outcomes with theoretical knowledge. Students highlighted that these discussions helped them understand why certain material choices were correct or incorrect, thereby deepening their conceptual understanding of Construction Materials. In addition, reflective learning journal submissions encouraged students to critically evaluate their learning process, identify mistakes, and document their improvement over time. This reflective practice was reported to strengthen metacognitive awareness and promote continuous learning improvement. Overall, students agreed that a structured feedback system significantly enhances engagement by supporting learning clarity, reflection, and continuous improvement.

Representative responses from the 22 participants include:

"When I get immediate feedback, I know straight away if my answer is right or wrong." (R2)

"The system feedback helps me learn faster because I can correct mistakes immediately." (R5)

"Lecturer discussion after the game helps me understand the topic better." (R9)

"Sometimes I don't understand why I am wrong until the lecturer explains." (R11)

"The reflection journal makes me think about what I learned in the simulation." (R14)

"Feedback after the simulation is very important for understanding materials." (R16)

"I can improve my decisions in the next simulation after feedback." (R18)

"Writing reflection helps me remember what I did in the game." (R20)

"Without feedback, I would not know how to improve." (R22)

Overall, all 22 respondents agreed that continuous feedback mechanisms comprising system feedback, lecturer debriefing, and reflective journaling play a critical role in sustaining engagement and improving learning outcomes in simulation-based Construction Materials education.

Recent studies emphasize that continuous feedback is a key factor in enhancing student engagement and learning effectiveness in digital and simulation-based learning environments. Immediate feedback has been shown to improve learner motivation, reduce cognitive errors, and support self-regulated learning by enabling students to adjust their understanding in real time (Hattie & Timperley, 2007; Wisniewski et al., 2020). In addition, lecturer debriefing after simulation activities is widely recognised as an essential pedagogical practice that strengthens conceptual understanding by connecting experiential learning with theoretical knowledge (Dufresne et al., 2022; Kolb, 2015). Reflective learning journals further enhance metacognitive skills by encouraging students to evaluate their learning process and identify areas for improvement (Moon, 2013; Zhan et al., 2021). These findings support the integration of a continuous feedback mechanism as a critical strategy in simulation-based Construction Materials education.

CONCLUSION

This paper aimed to propose strategies for improving student engagement in Construction Education through the use of an online simulation game in learning Construction Materials among Construction Management students. Based on qualitative data collected through semi-structured interviews and analysed using content analysis, the study successfully achieved this aim by developing a structured set of engagement strategies grounded in students lived experiences and learning needs. The findings identified five key strategic areas that collectively form the Online Simulation Game Engagement Strategy (OSGES) which are (i) integration of simulation into weekly learning activities, (ii) task-based simulation activities, (iii) gamified learning structures, (iv) collaborative learning integration, and (v) continuous feedback mechanisms. Each strategy was derived from consistent patterns in student responses, highlighting the importance of structured, interactive, and experiential learning design in enhancing engagement. Students emphasised that learning becomes more meaningful when simulation is embedded into regular lessons, guided by clear tasks, supported by gamification elements, strengthened through peer collaboration, and reinforced with continuous feedback. Collectively, these strategies demonstrate that student engagement in construction education can be significantly improved through a well-designed simulation-based learning approach that aligns pedagogy with interactive digital tools. The proposed OSGES framework provides a practical and systematic guide for educators to transform traditional lecture-based teaching into a more active, student-centred, and experiential learning environment. It also offers a foundation for improving teaching practices in Construction Materials education and potentially other construction-related disciplines. In conclusion, this study has successfully achieved its objective of proposing strategies for enhancing student engagement in construction education. The resulting framework contributes both theoretically and practically by offering a structured approach for integrating online simulation games into higher education pedagogy, particularly within construction-related programmes.

REFERENCES

1. Abdullah, M. N. L. Y., Hsien, O. L., Nagaratnam, S., & Leong, H. J. L. Y. K. (2024). Factors influencing undergraduate students' engagement in online learning: A PLS-SEM approach. *Learning: Research and Practice, 10*(2), 233–257. https://doi.org/10.1080/23735082.2024.2348997

2. Baghban, M. H. (2025). The effect of student active learning on awareness of students on environmental impacts of material selection for building application: A case study. *Lecture Notes in Civil Engineering*.
3. Bhatnagar, S., Jacoba, G., Devkar, G., & Arefazar, Y. (2023). A systematic review of lean simulation games in the construction industry. *Architectural Engineering and Design Management, 19*(6), 701–719. https://doi.org/10.1080/17452007.2022.2155604
4. Creswell, J. W., & Poth, C. N. (2018). *Qualitative inquiry and research design: Choosing among five approaches* (4th ed.). SAGE Publications.
5. Dichev, C., & Dicheva, D. (2017). Gamifying education: What is known, what is believed and what remains uncertain. *International Journal of Educational Technology in Higher Education, 14*(9). https://doi.org/10.1186/s41239-017-0042-5
6. Dufresne, R. L., Gerace, W. J., Leonard, W. J., Mestre, J. P., & Wenk, L. (2022). Classroom learning assessment techniques (CLATs): Effective feedback in active learning environments. *Journal of College Science Teaching, 51*(4), 56–63.
7. Elo, S., & Kyngäs, H. (2008). The qualitative content analysis process. *Journal of Advanced Nursing, 62*(1), 107–115. https://doi.org/10.1111/j.1365-2648.2007.04569.x
8. Epley, J. (2016). Learning by doing: Using an online simulation game in an international relations course. *Journal of Interactive Learning Research*.
9. ElGewely, M., & Nadim, W. (2020). Immersive virtual reality environment for construction detailing education using building information modeling (BIM). *Lecture Notes in Mechanical Engineering*.
10. Extremera, J., Vergara, D., Rubio, M. P., et al. (2020). Effects of time in virtual reality learning environments linked with materials science and engineering. *Advances in Intelligent Systems and Computing*.
11. Fan, H., & Froese, T. (2005). A web-based project management game for computer-assisted instruction. In *Proceedings of the Annual Conference - Canadian Society for Civil Engineering*.
12. Guest, G., Namey, E., & Chen, M. (2020). A simple method to assess and report thematic saturation in qualitative research. *PLOS ONE, 15*(5), e0232076. https://doi.org/10.1371/journal.pone.0232076
13. Hattie, J., & Timperley, H. (2007). The power of feedback. *Review of Educational Research, 77*(1), 81–112. https://doi.org/10.3102/003465430298487
14. Huang, Y.-M., Silitonga, L. M., Murti, A. T., & Wu, T.-T. (2023). Learner engagement in a business simulation game: Impact on higher-order thinking skills. *Journal of Educational Computing Research, 61*(1), 96–126. https://doi.org/10.1177/07356331221106918
15. Hrastinski, S. (2021). Digital collaboration: A research agenda. *Education and Information Technologies, 26*, 137–151. https://doi.org/10.1007/s10639-020-10234-5
16. Ilbeigi, M., & Bairaktarova, D. (2022). Work-in-progress: A gamified pedagogical system for teaching construction scheduling through active exploration. *Stevens Institute of Technology Research Output*.
17. Ilbeigi, M., Bairaktarova, D., & Ehsani, R. (2023). A gamified method for construction engineering education: Learning through guided active exploration. *arXiv preprint*. https://arxiv.org/abs/2405.05209
18. Ismail, I., Hasan, H. F. A., & Othman, M. Z. (2023). Factors influencing student engagement in open distance learning. *International Journal of Academic Research in Business and Social Sciences, 13*(6), 1862–1868.
19. Johnson, D. W., & Johnson, R. T. (2019). *Cooperation and the use of technology*. Interaction Book Company.
20. Kallio, H., Pietilä, A. M., Johnson, M., & Kangasniemi, M. (2016). Systematic methodological review: Developing a framework for a qualitative semi-structured interview guide. *Journal of Advanced Nursing, 72*(12), 2954–2965. https://doi.org/10.1111/jan.13031
21. Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development*. Prentice-Hall.
22. Laal, M., & Ghodsi, S. M. (2012). Benefits of collaborative learning. *Procedia - Social and Behavioral Sciences, 31*, 486–490. https://doi.org/10.1016/j.sbspro.2011.12.091
23. Lee, S., Nikolic, D., & Messner, J. I. (2015). Framework of the virtual construction simulator 3 for construction planning and management education. *Journal of Computing in Civil Engineering*.
24. Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. SAGE Publications.
25. Lucas, J., & Gajjar, D. (2022). Influence of virtual reality on student learning in undergraduate construction education. *International Journal of Construction Education and Research*.

26. Marchiori, R. S., & Song, S. (2024). A game-based learning method to promote soft skills in construction education. In *ASEE Annual Conference and Exposition Proceedings*.
27. Meadati, P., Juneja, P., Siddiqi, K., & Hayath, A. (2025). Learning environment using mixed reality information model. In *International Conference on Construction in the 21st Century*.
28. Meadati, P., Juneja, P., Siddiqi, K., & Hayath, A. (2024). Learning concrete formwork using 3D simulation game. In *International Conference on Construction in the 21st Century*.
29. Meadati, P., Akhnoukh, A. (2021). 3D scans—A new teaching tool in construction education. *Advances in Science, Technology and Innovation*.
30. Meadati, P., Aklinoukh, A. (2019). 3D scans—A new teaching tool in construction education. In *International Conference on Construction in the 21st Century*.
31. Mirhasani, S., Bosch, J., & Louis, J. (2025). Assessing the efficacy of virtual reality site visits to enhance remote learning experiences for civil and construction engineering students. In *Proceedings of the International Symposium on Automation and Robotics in Construction*.
32. Mubarrat, S. T., Min, B.-C., Shao, T., Smith, E. C., Benes, B., Magana, A. J., Mousas, C., & Kao, D. (2026). Game-based and gamified robotics education: A comparative systematic review and design guidelines. *arXiv preprint*. https://arxiv.org/abs/2601.22199
33. Moon, J. A. (2013). *Reflection in learning and professional development*. Routledge.
34. Nadeem, M., Oroszlanyova, M., & Farag, W. (2023). Effect of digital game-based learning on student engagement and motivation. *Computers, 12*(9), 177. https://doi.org/10.3390/computers12090177
35. Nikolic, D., Lee, S., Zappe, S. E., & Messner, J. I. (2015). Integrating simulation games into construction curricula: The VCS3 case study. *International Journal of Engineering Education, 31*(6), 1661–1677.
36. Nikolic, D., & Messner, J. I. (2012). Measuring the value of "all play and no work": Can rigorous assessment of simulation games drive innovative teaching in construction? In *Construction Research Congress 2012: Construction Challenges in a Flat World*.
37. Orr, L., & Weiner, N. (2025). Innovations and challenges in student engagement in higher education. *Innovations and Challenges in Student Engagement in Higher Education*.
38. Patton, M. Q. (2015). *Qualitative research & evaluation methods* (4th ed.). SAGE Publications.
39. Petrova, M. N. (2020). Exploring the gap between student-centred learning and students learning outcomes: A case-study of a materials for interior design class. In *Proceedings of the 22nd International Conference on Engineering and Product Design Education (E&PDE)*.
40. Rahat, M. R., & ElZomor, M. (2024). Leveraging an active-learning approach through online courses to foster sustainable, equitable, and resilient infrastructure concepts. In *ASEE Annual Conference and Exposition Proceedings*.
41. Raiser, S., Warkalla, B., Schneider, A., & Kaiser, K. (2018). "Will it blend?" Combining online and on-site elements in simulation games. *Professional and Practice-based Learning*.
42. Rose, M., Antonaci, A., Bonnet, M., & Klemke, R. (2025). Learning success, engagement and fun: Evaluating an educational game in higher education as replacement for a homework assignment. *Lecture Notes in Computer Science*.
43. Rogmans, T., & Abaza, W. (2019). The impact of international business strategy simulation games on student engagement. *Simulation and Gaming*.
44. Safiena, S., & Goh, Y. M. (2024). Authentic learning questionnaire for digital simulation games in higher education: A construction safety case study. *Education and Information Technologies*.
45. Sailer, M., & Homner, L. (2020). The gamification of learning: A meta-analysis. *Educational Psychology Review, 32*, 77–112. https://doi.org/10.1007/s10648-019-09498-w
46. Saleem, A., & Jeelani, I. (2024). Edu-tainment in STEM: Exploring the feasibility of television-based educational games in engineering education. In *ASEE Annual Conference and Exposition Proceedings*.
47. Safiena, S., & Goh, Y. M. (2024). Authentic learning questionnaire for digital simulation games in higher education: A construction safety case study. *Education and Information Technologies*.
48. Subhash, S., & Cudney, E. A. (2018). Gamified learning in higher education: A systematic review. *Computers in Human Behavior, 87*, 192–206. https://doi.org/10.1016/j.chb.2018.05.003
49. Sun, Y., Bhadaniya, P., Eiris, R., & Gheisari, M. (2026). Online construction site visit: Studying construction students' collaborative problem-solving behaviors. *Computers and Education: X Reality*.
50. Thomas, G. S. (2005). 'LANDTECH' computer based landscape construction learning modules. *Building Education and Research*.

51. Venter, M. P., Trafford, N., & Wolff, K. (2022). A proposed classification system for online forum content. In *IEEE IFEES World Engineering Education Forum - Global Engineering Deans Council (WEEF-GEDC) Conference Proceedings*.
52. Wisniewski, B., Zierer, K., & Hattie, J. (2020). The power of feedback revisited: A meta-analysis of educational feedback research. *Frontiers in Psychology, 10*, 3087. https://doi.org/10.3389/fpsyg.2019.03087
53. Yang, Q., Zhang, Y., & Lin, Y. (2022). Study on the influence mechanism of virtual simulation game learning experience on student engagement and entrepreneurial skill development. *Frontiers in Psychology, 12*, 772157. https://doi.org/10.3389/fpsyg.2021.772157
54. Yin, R. K. (2018). *Case study research and applications: Design and methods* (6th ed.). SAGE Publications.
55. Zhan, Y., Xu, Y., & Ye, H. (2021). Reflective learning journals and student engagement in higher education. *Active Learning in Higher Education, 22*(3), 189–203. https://doi.org/10.1177/1469787421990842
56. Zhong, L. (2023). Investigating students' engagement patterns and supporting game features in a personalized computerized role-playing game environment. *Journal of Educational Computing Research, 61*(3). https://doi.org/10.1177/07356331221125946