2026 ASEE ANNUAL CONFERENCE June 21–24, 2026 | Charlotte Convention Center, NC
Host Sponsor UNC Charlotte
Paper ID #50645

Gamification in Virtual Learning Environments to Enhance Student Engagement in Sustainability Education

Dr. Dalya Ismael, Old Dominion University

Dr. Dalya Ismael holds a Doctor of Philosophy degree in Civil and Environmental Engineering from Virginia Tech. She is currently an Assistant Professor of Civil Engineering Technology (CET) in the Department of Engineering Technology at Old Dominion University, where her research focuses on encouraging sustainable design and construction practices through behavioral interventions and visualization techniques. Dr. Ismael has over ten years of teaching and industry experience, and is a LEED Green Associate and an Envision Specialist.

Mohan Yang, Texas A&M University

Dr. Mohan Yang joined the Human Resource Development program at Texas A&M University as an assistant professor in 2024. He received his Ph.D. degree in Learning Design and Technology at Purdue University. Dr. Yang's research focuses on workforce preparation through training and development. Several research areas include integrating emerging technologies in training and education, leveraging instructional design for training effectiveness, examining transfer of training, online learning, and universal design for learning.

Gamification in Virtual Learning Environments to Enhance Student Engagement in Sustainability Education

Abstract

Sustainability courses often rely on static instruction that struggles to keep students engaged with complex, real-world challenges. There is a growing need for interactive digital environments that allow students to explore, collaborate, and apply sustainability principles in more engaging ways. This study examines how a gamified web-based 3D environment can enhance student engagement in an undergraduate Sustainable Building Practices course, and focuses on student perceptions of engagement and collaboration. Eleven engineering technology students participated in several course sessions conducted within an online 3D "classroom," where they created avatars, moved through the space using keyboard controls, interacted with peers in real time, and located course materials placed around the environment. The platform provided freedom to explore, communicate, and download materials, turning the experience into a game-like challenge that required navigation and teamwork. The intervention was guided by principles from gamification, Self-Determination Theory, and experiential learning. Student reflections were analyzed thematically for engagement, motivation, social presence, and collaboration. Results from qualitative reflections indicate that students perceived the VR-based activities as engaging, socially interactive, and supportive of collaborative design work. Students described increased enjoyment, strong peer communication, and a sense of shared presence during the intervention. Students reported that the exploratory, game-like setting helped them stay focused and connected during the course activities. Analysis suggests the activity aligned with conditions associated with autonomy, competence, and relatedness, which prior theory links to student engagement. These findings highlight the potential of simple, web-based 3D gamified environments to enrich sustainability education. The paper concludes with recommendations for integrating similar platforms into engineering courses and directions for future research on scalable, low-barrier digital engagement tools.

Keywords: Gamification; 3D Learning Environments; Sustainability Education; Student Engagement; Experiential Learning; Engineering Technology

1.0 Introduction

In sustainability education, engaging students in active learning is critical for motivating them to grasp complex, real-world challenges. Some instructional approaches may struggle to sustain student engagement with complex sustainability challenges, particularly for learners accustomed to interactive and immersive experiences [1]. Gamified virtual reality (VR) environments have emerged as a promising strategy to address this need by merging immersive simulation with game-like elements to create more motivating and engaging learning contexts. Gamification – the use of game design elements in non-game settings – has been shown to increase student motivation and participation in various educational domains [2]. Likewise, VR technology enables experiential learning by allowing students to actively *experience* and explore content in a simulated world, which can deepen understanding and engagement.

Recent advances in VR for education demonstrate enhanced student immersion and social presence, often associated with higher enjoyment and engagement [3]. In engineering and sustainability contexts, VR offers authentic problem-solving scenarios where students can collaborate as if in a real environment, but with the freedom to experiment without real-world consequences. By incorporating gamified features – such as avatars, 3D navigation, and collaborative challenges – VR learning environments may support students' psychological needs for autonomy, competence, and relatedness, which are fundamental to intrinsic motivation according to Self-Determination Theory (SDT) [4]. Prior research in engineering education has found positive impacts of gamification on academic performance and teamwork, noting that gameful approaches can foster a sense of belonging and encourage cooperative behavior among students [2].

This paper investigates the use of a gamified VR environment to enhance student engagement in a Sustainable Building Practices course. We replaced conventional instruction with a fully immersive VR experience in which students learned and collaborated inside a virtual world. The study focuses on the gamification aspects of the intervention – avatar-based interaction, spatial navigation, real-time team communication – and their effects on student engagement, motivation, and social presence. Theoretical framing is drawn from SDT, gamification in engineering education, and experiential learning principles, to interpret how and why the VR approach influenced the student learning experience. The following sections describe the instructional intervention and research methodology, present qualitative findings from student reflections, discuss the results in light of theory and prior work, and conclude with implications for engineering education practice and research.

2.0 Background

2.1 Gamification and Student Motivation

Gamification refers to integrating game elements (e.g. challenges, feedback, narrative, avatars) into non-game contexts to increase engagement. In educational settings, gamification has consistently been linked to higher student motivation and participation. A broad literature review by Hamari et al. found that most gamified learning interventions yield positive effects on student engagement, though outcomes can vary with context and implementation details [2]. Critically, gamification works by tapping into intrinsic motivators – it makes learning activities more *fun*, provides clear goals and rewards, and often introduces friendly competition or collaboration that sustains interest. According to **Self-Determination Theory (SDT)**, students are intrinsically motivated when their basic psychological needs are met **autonomy** (a sense of control and choice), **competence** (a sense of efficacy and achievement), and **relatedness** (a sense of social connection). Well-designed gamified environments can support these needs – for example, by giving learners freedom to explore (autonomy), instant feedback and attainable challenges (competence), and platforms for social interaction (relatedness). Satisfying these needs enhances students' internal motivation to engage with learning tasks [6]. In an engineering education study, Díaz-Ramírez (2020) reported that a gamified approach led to not only improved grades but also stronger teamwork and sense of belonging among students [2]. These social outcomes highlight that beyond making learning more enjoyable, gamification can cultivate a learning community where students feel connected and invested in collective success. This is especially relevant in sustainability education, where collaboration and shared purpose are key.

2.2 Virtual Reality and Immersive Learning

Virtual reality offers a computer-generated 3D environment in which learners can have **"realistic and immersive experiences"**. By engaging multiple senses and providing a first-person perspective, VR can closely simulate real-world contexts, aligning with Kolb's experiential learning cycle (concrete experience, reflective observation, abstract conceptualization, active experimentation). VR has been applied in engineering and science education to enable virtual field trips, realistic laboratories, and interactive simulations that would be impractical otherwise. Research indicates that VR-based learning environments can be engaging, interactive, and immersive for students. Lampropoulos and Kinshuk (2024) conducted a systematic review of virtual reality and gamification in education, concluding that **gamified VR environments were more motivating and engaging for students, offered greater opportunities for personalized and collaborative learning, and enhanced students' immersion and social presence**. Notably, VR can increase students' sense of *presence* – the subjective feeling of "being there" in the virtual space. This social presence aspect is vital for collaborative learning: when students embody avatars and co-exist in a virtual world, students often report strong feelings of connection with peers within avatar-mediated environments. A recent study by Ratan et al. (2025) found that students in a VR class experienced significantly higher social presence with both instructors and fellow students, which was associated with greater enjoyment and perceived learning, versus a conventional video-based class [3]. These findings suggest that VR can effectively foster the relatedness and interactivity that drive engagement.

2.3 Experiential and Gameful Learning in Sustainability Education

Sustainability and engineering educators have increasingly looked to experiential learning approaches to help students internalize concepts like sustainable design, ethics, and community impact. Immersive simulations and serious games allow students to "learn by doing" in contexts that mimic real challenges (e.g. urban planning with climate impacts) [3]. By placing learners in authentic roles (such as city planners or engineers in a virtual scenario), these methods can increase the relevance of content and stimulate deeper learning. Gamified VR in particular combines the strengths of experiential learning (authentic, hands-on engagement) with the motivational affordances of games (clear goals, feedback, and an immersive storyline) [3]. Prior work on immersive visualization in infrastructure planning suggests that spatially interactive environments can support exploratory reasoning and systems-level thinking related to sustainability and long-term resilience [7]. In the context of sustainable engineering, a gamified VR environment can, for example, let students explore a virtual city facing environmental challenges, collaborate on designing solutions, and immediately visualize the outcomes of their decisions. This approach not only makes learning more engaging but also can encourage perspective-taking and exploratory reasoning about sustainability challenges by **"experiencing"** the consequences of sustainability choices in a safe virtual setting [8]. Prior work has shown that engineers' perceptions of sustainability-related risk strongly influence design decisions, underscoring the value of instructional approaches that surface trade-offs and consequences in context [10]. Prior studies on game-based sustainability learning have reported improved student enthusiasm, greater retention of concepts, and a willingness to pursue further learning in sustainability topics (e.g. joining sustainability projects or competitions) [9] [11]. The literature thus provides a strong rationale for the use of a gamified VR pedagogical intervention to enhance student engagement, motivation, and collaboration in courses like Sustainable Building

Practices. Building on these insights, our study examines how such an intervention played out in a real classroom and the extent to which the anticipated benefits were realized.

3.0 Methodology

3.1 Course and Participants

The study was conducted in a junior-level course **CET 355: Sustainable Building Practices** at xxx xxxxxxx University. The course enrolled 11 undergraduate students majoring in Engineering Technology disciplines. The instructional intervention took place over the final four weeks of the semester as students worked on a sustainable infrastructure design project for the coastal city of Norfolk, Virginia, a region experiencing increasing precipitation variability and flood-related challenges [12]. Instead of regular in-person class meetings, students met in a virtual environment. Participation in those sessions was a required part of the course project, and all 11 students were organized into four project teams of 2–3 members each.

3.2 Gamified Learning Environment

The intervention consisted of three primary VR-based components:
(1) Collaborative exploration in the Spatial environment, where students navigated the virtual classroom and accessed materials.
(2) Immersive visualization of flooding scenarios within the virtual environment.
(3) Collaborative conceptual design sessions using Gravity Sketch, followed by refinement in traditional CAD software.

The virtual environment was implemented using *Spatial*, a multi-user collaboration platform. Students accessed Spatial using their laptops. Upon first entering the virtual space, each student created a personalized **avatar** to represent them (Figure 1). The avatars were cartoon-like 3D human characters, which the students could customize (e.g. appearance, clothing) to add a playful identity to their presence. The virtual "classroom" itself was a 3D model of an open collaborative space designed by the instructors, containing various points of interest: a central meeting area, interactive info boards and screens displaying course materials, and open areas for design activities (Figure 2). Movement in the virtual world was controlled via keyboard or mouse – students could **walk** around the space, **jump** or teleport to different locations, and pick up or interact with virtual objects. These navigational affordances introduced a game-like exploration element to the learning experience. Students could, for instance, walk up to a virtual bulletin board, click it to **"download"** a PDF of the Envision sustainability rating guidelines, or gather around a virtual table to discuss ideas, much like characters in a multiplayer game.

Figure 1. *Student avatars interacting in the Spatial VR environment during the sustainability class.*

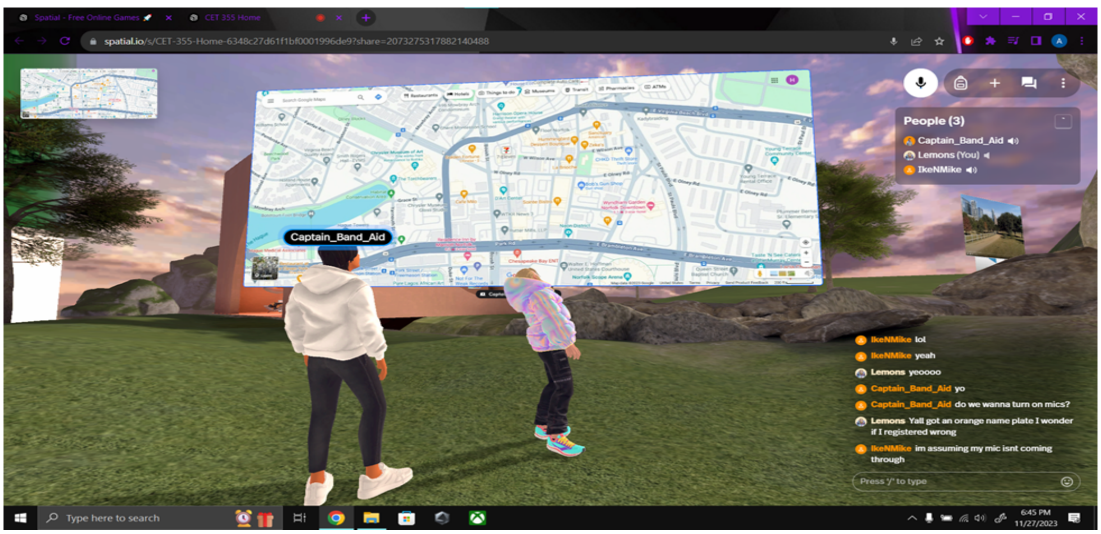

Figure 2. *The VR space contained virtual info boards (visible in the background) with course materials and allowed students to meet and communicate in real time. The use of avatars enabled a sense of co-presence – here two team members (avatars at center) converse and gesture as they plan their project.*

To leverage VR for the **design phase** of the project, we incorporated additional software tools: *Arkio* and *Gravity Sketch*. These are VR-based 3D modeling applications that allow multiple users to create and edit 3D models collaboratively. After initial meetings in the Spatial environment to review project requirements and brainstorm, each team moved into a private virtual design session using Gravity Sketch on the Quest headsets. In these sessions (scheduled during lab hours), team members co-created a prototype of their sustainable infrastructure solution – for example, a redesigned stormwater drainage system or a seawall – by sketching and manipulating 3D shapes in mid-air (Figure 3). The experience was highly interactive and gamified; students described it as *"drawing in 3D space, like a video game design tool."* One student would host the VR modeling space and others would join as avatars, each able to draw, resize, and assemble components of the design. Throughout, students communicated via the headset microphones, coordinating their actions much as gamers strategize in an online cooperative game. The VR design sessions typically lasted 30–45 minutes at a time, after which teams had tangible design artifacts (VR sketches) that they later exported and refined in traditional CAD software.

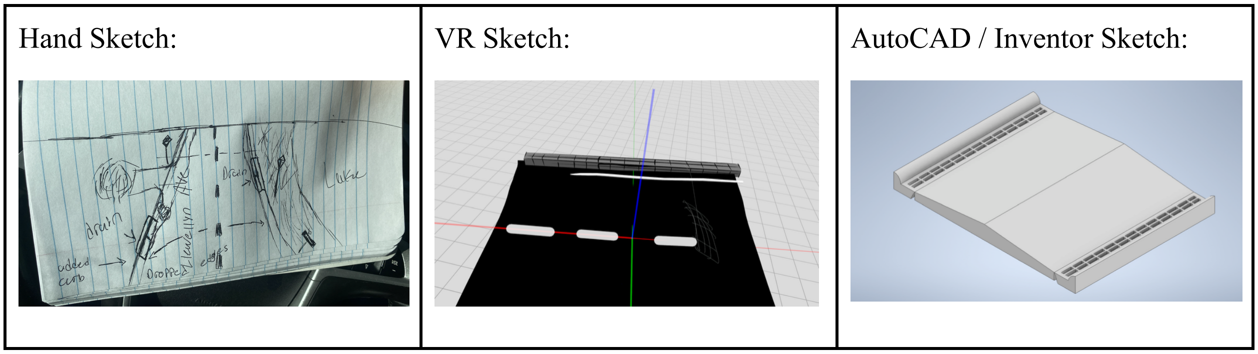

Figure 3. *Progression of example student design artifacts across modalities, showing the evolution from an initial hand sketch (left) to a collaborative VR-based conceptual model (center), and finally to a refined CAD model developed in AutoCAD/Inventor (right).*

3.3 Data Collection

To evaluate the impact on student engagement and related factors, we collected qualitative data in the form of written student reflections and conducted observations of student interactions in VR. At the conclusion of the project, each student submitted a **Reflective Summary** detailing their personal experience with the VR environment and their thoughts on how it affected their learning, motivation, and teamwork. These reflections were written as part of the course assignment (approximately 1–2 pages per student). Reflection prompts asked students to describe (1) their level of engagement during the VR activities, (2) how collaboration and communication unfolded within the virtual environment, and (3) perceived advantages and challenges of using VR for the course project. In addition, the instructor (and study author) was present in-world during many of the VR sessions to facilitate and observe. Informal observations – such as noting student enthusiasm, technical difficulties, or group dynamics in VR – were documented as field notes. While no formal survey instrument was used (given the small sample), these combined qualitative sources provided insights into the students' engagement and perceptions [5]. Reflections ranged from approximately 1–2 pages in length.

4.0 Results

We employed a qualitative thematic analysis to identify common themes in the student reflection data. Following guidelines by Braun & Clarke (2006), we first performed **open coding** on the reflection essays: each reflection was read closely, and discrete comments or sentences were labeled with initial codes (e.g. "felt fun/engaging," "technical learning curve," "better teamwork," "more creative ideas," "prefer VR to lecture," etc.). We then organized these codes into higher-order themes that correspond to the research focus on gamification and engagement. Through iterative discussion and comparison of codes, four salient themes emerged: **(1) Enjoyment and Motivation, (2) Social Presence and Communication, (3) Immersion and Exploration,** and **(4) Challenges and Adaptation**. We also triangulated these themes with the instructor's observations to ensure consistency (for instance, if several students wrote that they felt more connected as a team in VR, the observation notes were checked for instances of collaborative behavior or verbal camaraderie in the sessions). Finally, representative quotes for each theme were extracted from the reflections to be used as evidence in reporting the findings. Given the small number of participants, we opted for an in-depth descriptive approach rather than quantifying responses. The focus is on richly conveying the student experience and the mechanisms by which the gamified VR environment influenced their engagement and learning.

Enjoyment and Motivation in the Gamified Environment

All students found the VR environment to be **highly engaging and fun**, often describing the experience as different from their typical course activities. Many described the experience with terms like *"cool," "neat,"* and *"exciting."* One student wrote, *"The VR sketch was a fun process and I believe our sketch shows the basic grasp of what our project does."* Students emphasized the novelty of the medium as a positive factor – it **"was a new experience for most of us,"** and this novelty appeared to rekindle their enthusiasm for the coursework. Rather than feeling like an assignment, navigating the project in VR felt game-like. As one student put it: *"Spatial was an experience that really enhanced my outlook... Overall, a project where I could socialize and develop [in VR] made me more appreciative of the continuing education path I chose."* This comment illustrates how the gamified approach was perceived as motivating and enjoyable – by making learning enjoyable, it reinforced their appreciation for the subject and their education.

Several students mentioned that they were **motivated to invest more time and effort** because of the VR format. For instance, one student who admittedly had struggled with traditional coursework noted, *"I wish I had more time to build in there [VR]... it was a neat experience."* This suggests that the immersive, game-like nature of the task encouraged voluntary extra effort – a hallmark of intrinsic motivation. Another student compared the VR design session to playing a creative video game, saying it *"didn't feel like homework, it felt like we were all just building something together for fun."* Such statements indicate that the gamified VR environment helped transform an academic project into a *motivating* and even enjoyable activity, aligning with findings that gamification can increase students' willingness to engage in learning tasks. Many also described a sense of **achievement** from overcoming the challenges of VR modeling, which contributed to their confidence (competence need) and motivation to continue. One student proudly noted that after learning the VR tools, *"we managed to find the proper categories [in Envision] and flesh out our ideas [in VR]."* This reflects a growth in competence – the game-like challenge of mastering VR design was rewarding in itself.

Social Presence and Team Communication

A standout aspect of the intervention was students' reported sense of social presence and communication. By interacting as avatars in a shared virtual space, students felt *"more connected"* with their teammates compared to usual class interactions. One student commented that *"Spatial's meeting space... cultivated an innovative environment in which our group was able to flesh out our ideas."* The ability to see avatars representing peers, communicate via spatialized voice chat, and even use virtual gestures (like pointing at a model or giving a thumbs-up) created a strong feeling of co-presence. Students often referred to their teammates by avatar names and noted that working side by side in VR **"felt like we were all in the same room,"** despite being physically remote. This heightened social presence led to richer communication. For example, one reflection noted: *"Everyone was great with participating and communicating with each other. For [my teammate] and I, we got to learn how to operate the VR set because [another teammate] was teaching us how to sketch in VR."* Here we see that the environment not only allowed communication, but encouraged **peer teaching and support** – an indicator of a healthy team dynamic. The student who was more adept with VR took on a coaching role, guiding others through the new technology. Such peer mentoring might be less likely to occur in a traditional setting, but in VR the team essentially "played through" the learning curve together, like a guild in a game helping newbies level up. This dynamic strengthened team cohesion.

Students also reported feeling **greater camaraderie and engagement in group discussions** held in VR. The playful atmosphere of being avatars (some students chose humorous or imaginative avatar appearances) served as an icebreaker. *"It felt cool to work on a local project [in VR] that could affect our everyday lives,"* one student noted, *"and to do it together in a game-like setting made it even better."* Many reflections highlight that VR sessions were full of interaction – *"we talked through ideas in real time, pointed at things, even joked around – it kept everyone engaged,"* wrote one participant. This aligns with the concept that **relatedness** (social connection) was strongly supported, which according to SDT can boost motivation and engagement [6]. Indeed, students explicitly linked the social experience to feeling more involved: *"Spatial was a great interactive tool… a new and interesting way to collaborate and brainstorm,"* wrote one student, adding that it was **"great to actually *meet* and talk in that space"** rather than silently dividing work. In summary, the gamified VR environment functioned as a social learning space that increased presence and encouraged more organic, enthusiastic communication among team members. This likely contributed to more cohesive teamwork and a shared sense of purpose in the project. One team's reflection stated that they **"did not face any challenges [in collaboration] because everyone was a team player… participating and communicating with each other"**.

<u>Immersion, Exploration, and Creative Engagement</u>

The immersive nature of the VR experience allowed students to engage with the course content in a very **active and exploratory manner**. Unlike a classroom where learning is often passive, the VR environment prompted students to *move, seek, interact,* and thus learn by doing. Students noted that being able to physically explore a virtual environment made the learning feel **"real"** and exciting. One student described walking through their virtual design: *"We recreated Kaufman Hall [a campus location] in VR… being able to 'stand' in our design and look around was enlightening and allowed us to be more creative with our project."* This quote illustrates how immersion in VR spurred creativity – by visualizing their solution at full scale around them, students thought of new ideas and design improvements they might not have conceived on paper. This aligns with experiential learning ideals, as the VR gave them a concrete experience to reflect and iterate upon.

The *gamified freedom* to explore also contributed to engagement. Students enjoyed features like teleporting to different viewpoints, examining virtual infrastructure components up close, and even the simple novelty of using hand controllers to grab and manipulate objects. One student said, *"It was like exploring a level in a video game – we could roam around the city model and find the flooding spots we needed to fix."* This exploratory gameplay element kept students curious and involved. Furthermore, the immersive visuals and interactive models helped students engage with abstract concepts in a more concrete and visual manner. For example, a student noted that seeing flood simulations in VR (the instructors had placed an animation of rising water in the model) *"really hit home how serious climate change is… it gave an eye-opening perspective on our community's flooding."* Thus, VR not only engaged students but also reinforced learning outcomes by situating students within the sustainability problem, making it tangible and grounded in real infrastructure challenges faced by coastal communities [13].

Challenges and Adaptation to VR

While the response to the gamified VR intervention was overwhelmingly positive, students did encounter some **challenges** early on. The most common issue mentioned was the **technical learning curve** – initially, a few students struggled to adjust to the VR controls and interface. One student admitted, *"The V.R. was an interesting tool to use, but it took a little getting used to before I could draw properly, so [my partner] handled most of it [at first]."* Another student noted experiencing slight **motion sickness or eye strain** in the first session, writing that VR *"allowed me to understand the effects it can have on human functions such as blurry eyesight and attention to focus."* These physical discomforts are not uncommon in VR use, especially for newcomers. However, importantly, students reported that these issues diminished with practice. As they gained more experience across sessions, confidence grew. Teamwork also played a role in overcoming challenges: as mentioned, peers helped each other learn the ropes. *"Along the process of designing our VR sketch, [one student] was teaching us how to sketch in VR,"* wrote a teammate, illustrating that collaborative learning eased the adaptation. By the second or third VR meeting, all teams were fully operational in the virtual space, and technical hurdles had mostly been resolved. This reflects a short-term need to accommodate learning and comfort in VR, but not a long-term barrier.

Another challenge some cited was the **initial awkwardness** of interacting in VR. A few students felt shy or silly when first speaking as avatars or using gestures. One mentioned, *"It was definitely harder for some of us than others… each of us had a different experience with the virtual reality."* However, these differences evened out as the semester progressed. Students noted that by the end, everyone was contributing: *"Nevertheless, the experience was enlightening and allowed us to be more creative… it is safe to say we all benefited,"* wrote one participant after acknowledging the varying comfort levels. This statement underscores that despite early discomfort, ultimately *all* students gained value, suggesting a successful adaptation. From an instructor perspective, this highlights that providing a supportive environment and time for students to get accustomed to VR is crucial. Once past the initial learning phase, the gamified VR environment's benefits – increased engagement, creativity, and collaboration – clearly outweighed the challenges. This finding aligns with Ratan *et al.* (2025)'s recommendation that keeping VR sessions to manageable durations (around 30–45 minutes) and giving students time to familiarize themselves can mitigate fatigue and maximize benefits [3]. Indeed, in our course the VR meetings were typically under an hour, which students found enjoyable without being tiring.

5.0 Discussion

The high enjoyment and enthusiasm observed among students can be explained by the intervention's alignment with Self-Determination Theory's key motivators. First, **autonomy:** students in the VR environment had considerable control over their learning actions – they could explore freely, choose where to go in the virtual space, and make creative decisions in designing their project. This freedom provided a sense of flexibility within the VR sessions, thereby fulfilling the need for autonomy. Students' remarks about *"roaming like in a video game"* and not feeling like it was "homework" indicate they experienced a sense of volition and play, which is closely tied to intrinsic motivation[10]. Second, **competence:** the VR project provided clear goals (e.g. create a working design, master the VR tools) and immediate feedback (seeing one's design come to life, successfully using a tool after initial difficulty). Mastery experiences, such as learning to build a 3D model in Gravity Sketch, gave students feelings of accomplishment. When a student said *"we managed to find the proper categories and flesh out our ideas,"* it reflected growing confidence in their abilities. Many students explicitly mentioned pride in what they created in VR – a sign that the need for competence was met. Third, **relatedness:** arguably the most impacted need, as evidenced by the strong social presence. The collaborative, avatar-mediated nature of the VR sessions fostered peer connections and a team spirit. The quote *"everyone participated and communicated… [we] didn't face challenges because everyone was a team player"* exemplifies how relatedness was fulfilled; students felt part of a cohesive group with a shared mission. This sense of belonging and camaraderie is a powerful intrinsic motivator [2].

By satisfying autonomy, competence, and relatedness, the gamified VR environment created an optimal motivational climate. This led to students engaging more deeply and putting in extra effort willingly. It aligns with broader gamification research which emphasizes that gameful experiences work best when they tap into internal motivations rather than relying solely on external rewards [4] [2]. Notably, we did not implement points, badges, or grades as part of the VR experience – the motivation boost came organically from the experience itself. This suggests that students experienced the engagement as meaningful and enjoyable. Students were not just complying for a grade; they were genuinely interested and enjoying the learning process. For sustainability education, engagement and collaboration are important precursors to meaningful project participation.

The finding that VR increased social interaction and teamwork supports prior work on the value of presence in virtual learning [3]. Students reported that the VR environment supported continuous interaction and coordination during project work. One reason is that VR provided a *shared spatial context* – teammates could literally see the same objects and visualize each other's focus of attention by avatar gaze or pointing gestures. This shared spatial context appeared to support coordination during collaborative work (e.g. jointly inspecting a virtual model). It's similar to how co-located teams work together around a physical prototype, except here it was done virtually. The improved communication and peer support we observed mirror the concept of *collective efficacy* in education – the belief of a group in their joint capability often leads to better performance and resilience. When students said *"we brainstormed in Spatial and fleshed out ideas"* or taught each other VR skills, it indicated a high level of collective engagement. This also ties into the gamification element of **"team challenge"** – effectively, each project team was like a small guild tackling the quest of designing a sustainable solution. Research in gamified learning suggests that cooperative play and team-based quests can strengthen commitment and persistence among learners [4] [2]. Our students' unified front in overcoming VR challenges and completing their project demonstrates this effect. Furthermore, the enhanced relatedness likely made the learning experience more enjoyable overall – students felt supported and that they were *"in this together."* This emotional engagement is crucial in a subject like sustainability which can sometimes involve daunting problems; having a team to collaborate with can mitigate feelings of overwhelm and keep morale high.

Interestingly, the use of avatars added a slight degree of anonymity or freedom that may have equalized participation. For instance, a typically quiet student might feel more at ease speaking up through an avatar (somewhat shielded by the virtual presence), as noted by the student who realized contributing isn't only by writing but also by guiding peers in VR. This phenomenon is akin to how some people are more expressive in online games or forums than in person – the medium can reduce social anxiety. However, unlike text-based online learning, VR maintains richness of communication (tone of voice, 3D body language), so it captures many benefits of face-to-face interaction without some of the pressures. This balance likely helped every team member find their voice, thereby improving overall group communication. The outcome of *no major team conflicts or freeloading* (as students reported equal contributions) is notable; it suggests the gamified VR approach can encourage accountability and active participation from all members, a perennial challenge in group projects.

5.1 Implications for Educators

For future research, we recommend exploring gamified VR with larger and more diverse student populations, as well as in other subject areas of engineering, particularly those addressing climate and sustainability challenges [15]. These findings align with prior experiential learning initiatives that demonstrate the value of immersive, project-based environments in deepening student engagement and professional identity development [14]. Instructors seeking to implement gamified VR should consider the following: (1) **Clearly align VR activities with learning objectives:** In our case, the VR tasks (exploring flooding scenarios, designing infrastructure) were directly tied to course outcomes (understanding sustainability challenges, applying design principles). This ensured that the "fun" had pedagogical purpose and wasn't just novelty. (2) **Invest time in onboarding students with VR:** Early discomfort can be addressed by an orientation session. We provided an initial guided tour in Spatial and a brief tutorial on using the controllers, which, although not detailed in the findings, likely helped students get past the intimidation factor. (3) **Leverage the social aspect:** Group students in VR and give them collaborative tasks. The peer support and sense of shared presence are major advantages of VR – a design where students would work solo in VR might not harness the full power of the medium. We found teamwork in VR to be more than feasible; it was enriching. (4) **Be mindful of accessibility and inclusivity:** Not every student will take to VR immediately. Some may have motion sickness; others may be anxious. It's important to accommodate these (we had one student take a short break when dizzy, and we allowed the more comfortable team member to do initial heavy lifting in VR modeling until others caught up). Ensuring an inclusive experience might involve offering alternative modes for those who truly cannot use VR, though in our small sample all participated successfully after adaptation. (5) **Combine VR with reflection:** We gained a lot of insight from student reflections. Having students articulate what they learned or felt in VR consolidates those experiences into learning. It also forces them to step back and link the VR activity to course content (e.g. writing about how the VR design meets sustainability criteria). This kind of debrief is essential to turn experience into education (a key step in experiential learning theory).

5.2 Limitations

It should be noted that our study is a qualitative investigation with a small sample (N=11) in a single course. Thus, the findings, while compelling, are not automatically generalizable to all settings. The novelty effect of VR might wane if VR becomes more routine (though technology and content would also evolve). This study did not include direct assessment of content knowledge gains, design quality comparisons, or performance-based metrics. As such, conclusions are limited to student-reported perceptions of engagement and collaboration during the intervention. Future studies could incorporate control groups or pre/post assessments to quantify learning outcomes attributable to the VR intervention. Another limitation is that the VR implementation required certain resources – VR headsets, a prepared virtual environment, and instructor comfort with the technology. These requirements might be a barrier in some institutions. However, the cost of VR is decreasing, and many universities are creating VR labs, making such interventions increasingly accessible.

6.0 Conclusion

This study set out to explore how a gamified virtual reality environment could impact student engagement, motivation, and collaboration in a sustainability-focused engineering course. The results paint an encouraging picture: the immersive VR intervention not only captured students' interest but also actively involved them in their learning process. Students became players in a sustainability "game" navigating virtual floods, building virtual solutions, and learning together in a vivid 3D world. Such an approach transformed a traditional project into a lively educational adventure, yielding high reported enthusiasm and strong perceptions of teamwork during the intervention period.

From a pedagogical standpoint, the success of the intervention can be attributed to its holistic design. It simultaneously addressed the *affective* dimension (making learning enjoyable and motivating), the *social* dimension (fostering a learning community with strong presence), and the *cognitive* dimension (allowing hands-on problem-solving and creativity). These are areas that can be difficult to support consistently across instructional formats. The application of Self-Determination Theory in the design was evident in practice – students felt autonomous (choosing their approaches in VR), competent (mastering new tools), and related (working closely with peers), which in turn drove their intrinsic motivation. Likewise, experiential learning was at the core of the VR experience; by "doing and experiencing," students gained insights that no amount of textbook reading could offer. For instance, one group's understanding of urban flooding and infrastructure limitations was made more tangible by virtually witnessing those conditions and iteratively designing a fix.

For future research, we recommend exploring gamified VR with larger and more diverse student populations, as well as in other subject areas of engineering. It would be beneficial to quantitatively measure knowledge gains or skill development from VR-based learning and to compare different degrees of gamification (for example, VR with vs. without explicit game goals or rewards). Additionally, examining long-term effects – do students retain their learning or remain more interested in the field? – would shed light on the lasting impact of such interventions. Finally, as technology evolves (e.g. more affordable headsets, richer virtual worlds), continuous evaluation is needed to keep best practices updated.

The experience reported in this paper – while on a small scale – illustrates a pedagogical innovation that can help bridge the engagement gap in sustainability and engineering education. In the words of one student reflecting on the course, *"we all benefited from multiple aspects of this project in terms of trying something new, thinking critically, and learning more about our local infrastructure."* When students recognize and articulate such multifaceted growth, it suggests that the educational approach was positively received by students. Gamified learning environments, as illustrated in this study, can support active collaboration and participation among students.

References

[1] G. Lampropoulos and Kinshuk, "Virtual reality and gamification in education: a systematic review," *Educational Technology Research and Development*, vol. 72, pp. 1691–1785, 2024. DOI: 10.1007/s11423-024-10351-3

[2] J. Díaz-Ramírez, "Gamification in Engineering Education – An Empirical Assessment on Learning and Game Performance," *Heliyon*, vol. 6, no. 9, Article e04972, 2020. DOI: 10.1016/j.heliyon.2020.e04972

[3] R. Ratan, Q. Lin, C. Lim, R. Park, A. Lover, E. Han, D. Jang, A. P. Leith, and J. N. Bailenson, "Time matters in VR: Students benefit from longer VR class duration, but certain outcomes decline after 45 minutes, with large individual variance," *Computers & Education*, vol. 235, 2025, Article 105328. https://doi.org/10.1016/j.compedu.2025.105328

[4] R. M. Ryan and E. L. Deci, "Self-Determination Theory and the Facilitation of Intrinsic Motivation, Social Development, and Well-Being," *American Psychologist*, vol. 55, no. 1, pp. 68–78, 2000. DOI: 10.1037/0003-066X.55.1.68

[5] Ismael, D. (2023), *Enhancing online hands-on learning in engineering education: Student perceptions and recommendations* [Paper presentation]. 2023 ASEE Annual Conference & Exposition, Baltimore, Maryland. https://doi.org/10.18260/1-2--43358

[6] R. Ismailova, C. Dichev, and D. Dicheva, "Estimating engagement in gamified activities," *Proceedings of the 2022 IEEE International Conference on Teaching, Assessment and Learning for Engineering (TALE)*, Hong Kong, China, 2022, pp. 447–452. https://doi.org/10.1109/TALE54877.2022.00079

[7] Ismael, D. (2024). Immersive visualization in infrastructure planning: Enhancing long-term resilience and sustainability. Energy Efficiency, 17(7), 83. https://doi.org/10.1007/s12053-024-10183-3

[8] Won, M., Ungu, D. A. K., Matovu, H., Treagust, D. F., Tsai, C.-C., Park, J., Mocerino, M., & Tasker, R. (2022). Diverse approaches to learning with immersive virtual reality identified from a systematic review. Computers & Education, 188, Article 104701. https://doi.org/10.1016/j.compedu.2022.104701

[9] Alnuaimi, M. A., & Awad, M. A. (2025). VR environment support for STEM students – a case study. Interactive Learning Environments, 1–19. https://doi.org/10.1080/10494820.2025.2527168

[10] Ismael, D., & Shealy, T. (2018). *Sustainable construction risk perceptions in the Kuwaiti construction industry*. *Sustainability, 10*(6), 1854. https://doi.org/10.3390/su10061854

[11] Ismael, D., & Shealy, T. (2024). *Reframing sustainability rating systems to emphasize interconnected benefits increases sustainable design practices among engineers*. *Journal of*

Construction Engineering and Management, 150(8), 04024086. https://doi.org/10.1061/JCEMD4.COENG-14590

[12] Chathuranika, I. M., & Ismael, D. (2025). *Integrating satellite-based precipitation analysis: A case study in Norfolk, Virginia*. *Eng, 6*(3), 49. https://doi.org/10.3390/eng6030049

[13] Chathuranika, I. M., Asante, A., Borhani, F., Wang, X., Erten-Unal, M., & Ismael, D. (2026). Performance assessment and design improvements for an urban coastal detention basin under intensifying rainfall extremes. *Frontiers in Built Environment*, 12, 1731955. DOI: https://doi.org/10.3389/fbuil.2026.1731955

[14] Ismael, D. and Ayala, O.M., 2023. Beyond the Classroom: Experiential Learning with Engineers Without Borders in Guatemala. In: ASEE Annual Conference and Exposition, Conference Proceedings. Doi: https://doi.org/10.18260/1-2--42365

[15] Erten-Unal, M., Ismael, D., & Considine, C. L. (2023, June 25-28). *Preparing students to solve challenges related to a changing climate* [Paper presentation]. 2023 ASEE Annual Conference & Exposition, Baltimore, Maryland. https://peer.asee.org/43955