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Research Article

GAME-BASED LEARNING WITH MINECRAFT: FOSTERING ENGAGEMENT IN MECHANICAL-ELECTRICAL-PLUMBING SYSTEMS EDUCATION

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ABSTRACT

Minecraft serves as an alternative tool for architectural education, offering an interactive and customizable platform for diverse learning purposes. This study explores the application of Minecraft in BIM-based MEP education, utilizing Redstone circuits and water channels to replicate electrical and piping systems. Students constructed Redstone-powered farming systems to simulate water and ventilation logistics, gaining practical experience in design and coordination. The workshop emulated AEC industry practices from predesign to construction, incorporating bidding, resource management, and system optimization. Teams allocated resources, addressed construction challenges, and refined circuit designs, with success measured by system efficiency, design optimization, and achievement of learning objectives. Integrating Minecraft as a game-based learning tool enhanced student engagement and supported independent learning. Collaborative problem-solving strengthened teamwork and adaptability, enabling both experienced and novice players to overcome design challenges and technical constraints. Findings indicate that students improved their interest in learning, strategic planning, resource management, and collaboration skills. The interactive environment fostered autonomy and problem-solving abilities. By assuming design and coordination roles, students gained valuable insights into AEC workflows. This study highlights Minecraft's potential as an educational tool in architectural training and its real-world applicability.

I. Introduction

The Architecture, Engineering, Construction, and Operation (AECO) industry relies heavily on interdisciplinary collaboration to deliver complex projects. Building Information Modelling (BIM) has become a key technology in this process, as it streamlines workflows, enhances coordination, and supports data-driven decision-making among stakeholders (Li & Yang, 2017). With the growing adoption of BIM, the integration of Mechanical, Electrical, and Plumbing (MEP) systems has become particularly important for reducing design conflicts, minimizing rework, and improving overall efficiency (Jadhav, 2022; Wagiri et al., 2023).

Despite its importance, BIM-integrated MEP education remains underdeveloped, especially at the undergraduate level (Zhang et al., 2021). This gap is largely due to limited teaching resources, a shortage of trained instructors, and difficulties in sustaining student engagement (Puolitaival & Forsythe, 2016; Yilei Huang, 2018). Traditional MEP courses often emphasize technical specifications and isolated components, while giving less attention to system integration, performance evaluation, or resource management (Palomera-Arias & Liu, 2015). In Taiwan, the focus is often placed on equipment functionality, which leaves students with little opportunity to develop systemic thinking or engage in collaborative, project-based learning. As a result, students struggle to stay motivated and to fully grasp abstract MEP concepts.

Scholars have argued for the need to simplify and contextualize MEP education in order to enhance engagement and learning effectiveness (Jadhav, 2022). Building on this idea, the present study explores the research question: Can a Minecraft-based Cooperative Problem-Based Learning (CPBL) workshop improve engagement and support understanding of foundational MEP concepts among second-year architecture students? Previous studies have shown that game-based learning (GBL) and gamification foster student interest, promote experiential learning, and enhance cognitive engagement, particularly when teaching abstract concepts (Caponetto et al., 2014; Nkadimeng & Ankiewicz, 2022; Shin & Bryant, 2015). In Taiwan, where 93.2% of students regularly play digital games, research has also linked gaming to improved focus, collaboration, and academic performance (Tsai et al., 2020). This context suggests that adopting GBL could be especially effective for MEP education.

Minecraft, one of the most widely used sandbox games worldwide, provides an open, interactive environment that supports collaborative learning. Its mechanics, such as Redstone circuits and water flow, can be adapted to represent electrical and plumbing systems in a simplified but engaging way (Bar-El & E. Ringland, 2020; López Méndez et al., 2017). Previous research has demonstrated Minecraft's educational potential across diverse subjects, from mathematics and programming to architecture (Nebel et al., 2016). In this study, Minecraft is combined with a CPBL approach in which students take on role-based responsibilities within a simulated AECO environment. The workshop was structured into four phases: (1) MEP and Minecraft training, (2) site selection and bidding, (3) design and construction, and (4) final presentations and evaluations. By situating students in an immersive and collaborative learning context, the study aims to increase motivation while strengthening conceptual understanding of MEP systems.

2. Literature review

2.1 Challenges in BIM-Based MEP Education

Building Information Modelling (BIM) has transformed the AECO industry by improving collaboration, design coordination, and data management (Wagiri et al., 2023). However, applying BIM to educational settings, especially for MEP systems, remains difficult.

Challenges include the absence of standardized curricula, limited teaching resources, and a lack of hands-on training (Li & Yang, 2017; Yilei Huang, 2018; Zhang et al., 2021). Traditional MEP instruction is often theory-heavy and teacher-centred, focusing on equipment specs rather than system integration, coordination, or estimation (Palomera-Arias & Liu, 2015). As a result, students are underprepared for real-world BIM-MEP integration. Jadhav (2022) stresses the need for simplified, hands-on methods to increase engagement and understanding. Likewise, Zhang et al. (2021) advocate for role-based, collaborative activities that mirror industry practices and bridge the gap between theory and application.

2.2 Cooperative, Student-Centred Learning Approaches

To address of traditional teacher-centred MEP instruction limitations, education is shifting toward student-centred methods like Cooperative Problem-Based Learning (CPBL), which merges open-ended problem-solving with collaborative teamwork. In CPBL, students take on defined roles to solve problems in team settings, simulating professional workflows (Yusof et al., 2012; Zhang et al., 2021). This approach has shown success in various disciplines. For example, Maskell and Grabau used it in embedded systems education and Panlumlers and Wannapiroon applied it to online learning. Sancho et al. (2009) highlight how combining CPBL with digital games enhances motivation and links theory with practice, critical for MEP education. These methods align with student-centred learning principles that promote autonomy, critical thinking, and collaboration (Sajben et al., 2020; Tangney, 2014). Together, CPBL and student-centred learning offer a strong foundation for developing both technical and teamwork skills essential for BIM-integrated MEP training.

2.3 Game-Based Learning with Minecraft for MEP Education

Game-Based Learning (GBL) uses gameplay to improve engagement, motivation, and problem-solving through project-based, interactive scenarios (Sancho et al., 2009; Yusof et al., 2012). Minecraft, a sandbox game, is particularly effective for GBL due to its open-ended, collaborative design (Bar-El & E. Ringland, 2020). It allows students to build, simulate, and experiment with simplified mechanics like Redstone circuits and water flow, representing electrical and plumbing systems. This makes abstract concepts more accessible and practical. Minecraft has been successfully used across subjects such as math, programming, ecology, and architecture (Nebel et al., 2016), and has been shown to be effective in teaching programming (Sajben et al., 2020), atomic structures (Nkadimeng & Ankiewicz, 2022), mathematics (Shin & Bryant, 2015), spatial design (López Méndez et al., 2017), and sustainability (Andrade et al., 2024). In MEP education, Minecraft supports collaborative design and system simulation. When paired with CPBL, it enhances strategic planning, role-based interaction, and immersive learning. This study adopts a Minecraft-CPBL framework to foster motivation, collaboration, and applied understanding in a BIM-integrated MEP curriculum.

3. Methods

3.1 Scope and Background Settings

In BIM, the Level of Development (LOD) defines the model's detail and reliability across project phases, from conceptual design to construction. The MEP system design progresses through LOD 100 to 500 (Latiffi et al., 2015), aligned with schematic design (SD), design development (DD), construction documentation (CD), and construction administration (CA). Early stages focus on spatial planning, while later stages refine equipment details, clash detection, and system integration. By LOD 400, the model provides as-built data with complete geometric and property information (Shin & Park, 2022).

This study focused on the LOD 100–150 stage, where MEP systems are conceptual and abstract. A four-session Minecraft-based workshop was developed for second-year architecture students to simulate early-stage MEP planning and assess engagement and motivation. Students worked in teams of four to five, each assigned specific roles, and used limited in-game currency to bid for land, manage resources, and construct electrical, water, and mechanical systems. The exercise emphasized spatial planning, system optimization, and collaborative problem-solving within a game-based learning framework.

Table 1 – Progress of Minecraft MEP Game-Based Lecture

Workshop Sessions	**Schemes**
Session 1	General Introduction, Game Rules, and Sites Introduction
Session 2	Site planning, Facilities Configuration and Bidding
Session 3	Material Marketing and Construction
Session 4	Result Performance and Evaluation

Source: Workshop's Syllabus

The Java Edition of Minecraft, hosted on ATERNOS.org, was used as the main educational platform, allowing students to collaborate in a shared environment. Redstone mechanics simulated electrical systems, while water and hopper elements represented plumbing. Farming machines acted as mechanical components. These in-game features were mapped to real-world MEP systems (see Table 2).

Table 2 – Mapping Minecraft Mechanisms to MEP Systems

Item	**Game Mechanism**	**Real-World Equivalent**	**Description**
Redstone	Functions like electrical circuits powering lamps, hoppers, pistons, etc.	Electrical System	Simulates wiring and energy flow for circuit logic and power distribution.
Water	Used for irrigating, moving items, and shaping terrain.	Plumbing	Simulates fluid transport for irrigation, waste, and cooling systems.
Farming Machines	Produce crops like wheat, carrots, and potatoes.	Mechanical Equipment	Represent systems with outputs; plan layout and manage transport.

Source: Lecture Planning, https://minecraft.wiki/

3.2 Workshop Implementation

In the first stage, site selection and bidding, students were introduced to five distinct plots, each with unique terrain and design challenges. Since the game environment lacks real-world physical limitations, artificial constraints were implemented to simulate realistic conditions. The maximum allowable height for structures, including farming machines and collection points, was set at 10 blocks (Figure 1), measured from the highest point of the machine's base. Additionally, plumbing and electrical networks were permitted to extend up to a maximum height of 13 blocks.

Figure 1: Sites and structural height restrictions in the Minecraft world. Left: The green areas represent designated building sites. Middle: Example of a farming machine illustrating the maximum allowable height of 10 blocks for structures. Right: Sectional view showing how the height limitation applies across different terrain levels.

Source: Authors, Lecture Examples

Within the given constraints, students developed site plans and bid for preferred locations according to their budgets. Variations in elevation and terrain led teams to adopt different design strategies. As noted in the Minecraft Wiki, agricultural products require distinct planting methods and exhibit different growth rates; these differences influenced crop values, as outlined in Table 3. Students incorporated this information to formulate site-specific strategies aimed at maximizing efficiency. Table 4 summarizes the strategies and expected configurations proposed during the second stage of the exercise, while Figure 2 illustrates a student design produced during material trading in a simulated market over a four-week period.

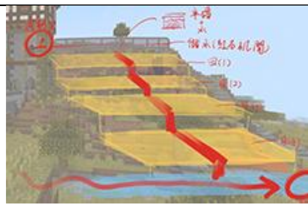
Table 3 – Minecraft Agricultural Products: Rate, Price, and Category

Types	Rate / Score	Price	Category
Wheat	1	10	Single Harvested
Beetroots	1	10	Single Harvested
Cactus	1.11	9	Multiple Harvested
Sugarcane	1.11	9	Multiple Harvested
Pumpkin	2	5	Multiple Harvested
Kelp	2.461	4	Multiple Harvested
Potatoes	3.714	2.7	Single Harvested
Carrots	3.714	2.7	Single Harvested
Bamboo	5.58	1.7	Multiple Harvested
Watermelon	10	1	Multiple Harvested

Source: Lecture Materials

Table 4 – Strategies for Different Sites

Sites Image	Description	Sites Image	Description
 Site 1	Flat terrain with dense trees. The team placed five machines across the site to maximize usable space.	 Site 4	Followed the natural water path with two machines near the collection point. A wheat machine was added on the flat north side for efficiency.

 Site 2	Located in a low-lying central area, machines were positioned in the lower region, with electrical circuits around. The focus was on high-profit crops.	 Site 5	Steep incline. Machines were built step-by-step along the slope. Chosen crops (potatoes, wheat, carrots) matched the terrain.
 Site 3	Two elevation levels. Machines were arranged along the slope to diversify crop types and boost income.		

Source: Students' Homework 1: Site Planning

Figure 2: Student-built farming systems and pipelines in Minecraft. The images depict cactus, bamboo, and sugarcane farms; crop fields; Redstone circuits; and water channels, with red arrows indicating resource flows and the simulation of MEP systems.

Source: Lectures

In the final session, each team was given 20 minutes to present its project, justify design choices, and harvest crops. Sales were determined using the values in Table 3, where rates and scores reflected both crop type and regrowth time for multiple-harvest varieties. Most teams cultivated a diverse mix of crops to maximize earnings and improve overall performance.

4. Results and Discussion

Twenty-five second-year students participated in the Minecraft-based MEP workshop: 14 with no Minecraft experience (ExG), 10 experienced (IExG), and 1 who did not state experience. Most had no prior exposure to MEP coursework, though many knew Revit as a modelling tool rather than for MEP coordination or cost/resource management. Participants varied in Minecraft experience, which influenced initial engagement and is explored in the subsections below. Effectiveness was evaluated via questionnaires, Q&A discussions, and student presentations. Overall, students demonstrated increased interest in MEP concepts through collaborative, game-based learning.

4.1 Students’ Experience and Game Mechanics

Interaction was shaped by prior Minecraft experience, assigned roles, and grasp of game mechanics. Of 25 students, 56% (n=14) were ExG, 40% (n=10) were IExG, and one did not state experience. As shown in Table 5, early control friction was concentrated in ExG, with all “very challenging” responses originating from this group, whereas a substantial proportion of IExG did not perceive the controls as challenging. This finding supports the claim that, although familiarity facilitates initial engagement, it is not the primary determinant of learning outcomes.

Table 5 – Control Difficulty by Experience

Control difficulty	**ExG (n=14)**	**IExG (n=10)**	**Experience NR (n=1)**	**Total (n=25)**
Very challenging	4 (29%)	0 (0%)	0 (0%)	4 (16%)
Somewhat challenging	8 (57%)	1 (10%)	0 (0%)	9 (36%)
Easy	1 (7%)	0 (0%)	0 (0%)	1 (4%)
Neutral/not stated	1 (7%)	9 (90%)	1 (100%)	11 (44%)

Source: Authors’ evaluation through questionnaires, Q&A discussions, and student presentations

Regarding MEP understanding (Table 6), prior Minecraft experience eased control use but did not guarantee stronger comprehension. Half of ExG participants (7/14) and approximately 70% of IExG participants (7/10) reported only partial understanding. Even experienced players encountered difficulties with abstract MEP planning, highlighting both the domain-specific cognitive demands and the representational limitations of Minecraft for complex coordination tasks. From a pedagogical perspective, the absence of a strong link between experience and understanding is encouraging, as it suggests that the game’s learning curve is not a major barrier and that mixed-experience cohorts can engage productively with MEP concepts.

Table 6 – MEP Understanding after the workshop (by experience)

Understanding Level	**ExG (n=14)**	**IExG (n=10)**	**Experience NR (n=1)**	**Total (n=24 responses)**
Partial	7 (50%)	7 (70%)	1 (—)	15 (62.5%)
Neutral	5 (36%)	1 (10%)	0	6 (25%)
Full	1 (7%)	2 (20%)	0	3 (12.5%)
Non-response	1 (7%)	0	0	—

Source: Authors’ evaluation through questionnaires, Q&A discussions, and student presentations

Despite the above, 76% of students found Minecraft beneficial for learning. Among IExG, 70% (7/10) said it increased their interest. ExG responses were more varied: 20% “very helpful” and 30% neutral, suggesting enthusiasm grows with fluency in mechanics, but meaningful learning is still achievable across experience levels.

4.2 Students' Interaction and Self Learning in the Workshop

To analyse students' interaction during the Minecraft-based MEP workshop, responses from the interview questions were examined:

- What was the most impressive event in the Minecraft workshop?
- What kind of architectural experience do you think your role supports?
- How do you think Minecraft contributes to architectural design?
- What is your overall satisfaction with the workshop? Would you like to see similar courses in the future?

Responses were categorized into ten themes: Architectural and Spatial Planning, MEP & Pipeline Configuration, Resource Management, Self-Learning, Game-Based Engagement, Hands-on Experimentation, Collaboration, Course Structure, Automation & Logic, and Construction Methods. The most frequently cited were Architectural and Spatial Planning and MEP & Pipeline Configuration (76 combined responses), with students emphasizing spatial optimization and pipeline layout. Some of their reflections were:

> *『透過有限資源與策略規劃，我們學會了團隊合作、空間運用與效率管理，體驗建築設計在虛擬世界的實踐價值。』*
>
> *(Translation: "Through resource limitations and strategic planning, we learned collaboration, spatial configuration, and efficiency management to experience the practical value of architectural design in the virtual world.")*
>
> *『可以更好的去規劃空間，合理的運用以及分配每個工作區塊，將有限的空間給效益最大化。』*
>
> *(Translation: "It allows for better space planning, rational use, and efficient allocation of each work area, maximizing the benefits of the limited space.")*
>
> *Similarly, in the "MEP & Pipeline Configuration" category, students mentioned the importance of Redstone circuits and pipeline integration for simulating electrical and plumbing systems:*
>
> *『紅石機關是我對本次課程印象較深的，我以前有稍微接觸Minecraft但不是非常擅長操作，藉由課程安排讓我體驗紅石機關的有趣以及操作手法。』*
>
> *(Translation: "Redstone mechanisms left the deepest impression on me in this course. Through the course, I experienced the fun and mechanics of Redstone devices and learned through experimentation.")*

Students commonly noted that resource constraints and design planning improved their understanding of real-world architectural processes. In the MEP & Pipeline Configuration category, many highlighted Redstone circuits as both challenging and rewarding, especially for those with limited prior experience.

Frequent keywords across responses included "collaboration", "game mechanics familiarity", and "Redstone circuit complexity", reflecting a strong emphasis on teamwork, problem-solving, and logical design. Students worked together to troubleshoot and optimize their systems and frequently delegated roles and tasks to manage complexity.

Self-learning was also notable: 88% of students reported using external resources like YouTube, and 95% found these helpful. Around 80% expressed a sense of accomplishment from their independent efforts, with one student noting that designing pipelines and farms with Redstone was challenging but manageable through online tutorials. One student mentioned:

> *『整個管線的安排，還有農場的設計，因為以前比較少接觸紅石機關，所以這次針對紅石機關來設計確實是蠻困難的，但還好網路上都有影片教學可以參考。』*
>
> *(Translation: "The entire pipeline layout and farm design were challenging because I had little prior experience with Redstone mechanisms. However, online video tutorials provided helpful references.")*

4.3 Limitations

This study has several limitations. First, the sample size was relatively small (n=25) and limited to second-year architecture students, which constrains the generalizability of findings. Second, the workshop lasted only four sessions, providing a short-term view of engagement and learning outcomes without assessing long-term retention or skill transfer. Third, the focus was restricted to the conceptual LOD 100–150 stage of MEP design. While suitable for early-stage exploration, this excludes more advanced levels of detail and integration that are critical in professional BIM practice.

4.4 Future Work

Future research should build on this pilot study in three directions. First, a larger-scale study across multiple cohorts and institutions would provide more robust evidence and allow for cross-context comparison. Second, extending the workshop into a semester-long course would make it possible to evaluate long-term knowledge retention and the sustainability of student engagement. Third, follow-up studies could integrate more advanced BIM tools (e.g., Revit MEP or Navisworks) after the Minecraft workshop to assess whether the game-based foundation supports students in transitioning to professional platforms. Additionally, longitudinal research could examine how game-based MEP learning shapes teamwork, problem-solving, and interdisciplinary collaboration skills over time.

5. Conclusion

This study explored the use of Minecraft as an educational tool for a BIM-based MEP workshop for undergraduate students. The findings indicate that game-based learning can enhance students' interest in MEP concepts and BIM education. Although Minecraft's simplified mechanics do not fully replicate real-world engineering complexities, they effectively support the teaching of fundamental principles in architectural and systems planning. The collaborative and competitive structure of the workshop promoted active learning, teamwork, and strategic thinking. The use of a Minecraft server facilitated collaborative problem-solving, hands-on engagement, and encouraged students to independently explore more complex circuit systems through online resources. Furthermore, student feedback indicated strong support for continuing the Minecraft-based workshop as an optional component of the curriculum.

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