

Game-Based Learning in Piped Services Engineering Education: Enhancing Student Engagement and Learning Experiences

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Abstract

This paper evaluates the integration of Game Based Learning (GBL) into the SBS5221 *Piped Services* module of the BEng (Hons) in Building Services Engineering programme at the Technological and Higher Education Institute of Hong Kong (THEi). Traditionally delivered through lectures, tutorials and laboratory sessions, the module has faced challenges in engaging Generation Z students, who prefer interactive and digitally enriched learning environments. To address this, a Unity-based online mini-game was developed to simulate a cold water supply system design for a domestic building. The study involved 42 Year-3 students. The effectiveness of GBL was assessed using pre- and post-game quizzes and a questionnaire survey. Quiz results showed an average improvement of 35.0%, with the highest gain (50.0%) observed in pipework design considerations. A paired-samples *t*-test confirmed that the improvement was statistically significant, demonstrating a strong positive impact on student learning outcomes. Survey results further supported these findings: 83.3% found the game easy to navigate, 80.9% rated it engaging, 76.2% reported improved understanding of technical concepts and 83.3% felt more confident in applying theoretical knowledge in practice. Overall, the GBL adopted in this case effectively bridged theory and practice. While students suggested refinements such as more advanced scenarios and improved navigation, the findings highlight the potential of GBL to modernise engineering education and enhance professional preparedness.

Keywords: engineering education, game-based learning, piped services, student engagement, teaching

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Introduction

Rapid technological advancement has transformed students' learning expectations. Generation Z, raised in digital environments shaped by video games and interactive platforms, increasingly prefers immersive and engaging learning experiences. Traditional teaching methods based on passive knowledge transmission often struggle to meet these expectations (Galloway, 2008), particularly in technical disciplines such as building services engineering.

SBS5221 *Piped Services* is a Year-3 core module in the BEng(Hons) in Building Services Engineering programme at THEi. It develops essential competencies in pipe sizing, material selection, system design and compliance with local waterworks regulations, which are skills critical for professional practice in dense urban contexts like Hong Kong. However, conventional pedagogies, such as lectures, tutorials and laboratory sessions, may not sufficiently engage students (Ohland et al., 2008; Seymour & Hewitt, 1997). While lectures deliver theoretical knowledge and laboratories provide practical exposure, these formats often lack the interactivity preferred by contemporary learners, potentially reducing motivation and learning effectiveness.

To address this gap, this study integrates game-based learning (GBL) into the module. A custom-designed online mini-game was developed to simulate real-world plumbing system challenges, enabling students to apply theory in practical contexts. The study evaluates the effectiveness of GBL through pre- and post-game quiz analysis and a questionnaire survey assessing usability, engagement and educational impact.

Game-Based Learning

GBL integrates gaming mechanics into educational, offering an interactive alternative to traditional, lecture-centred approaches (Price, 2009). By immersing students in realistic scenarios that require critical thinking, decision-making and problem-solving, GBL promotes active engagement rather than passive knowledge acquisition.

In the SBS5221 *Piped Services* module, GBL was implemented through a Unity-based online mini-game simulating cold water supply system design for residential buildings. Students designed and connected pipework while considering technical, economic and sustainability factors. Tasks included calculating water pressure and flow rates, selecting appropriate pipe sizes and materials, and ensuring compliance with local waterworks regulations. This simulated environment enabled students to apply theoretical knowledge in contexts resembling professional practice (Hwang et al., 2009).

Research highlights the benefits of GBL in enhancing motivation, engagement and knowledge retention (Apra & Ifenthaler, 2021). Immediate feedback and immersive gameplay support deeper understanding, particularly for digital native learners who favour interactive, hands-on experiences (Deshpande & Huang, 2011). However, in building services engineering, empirical evidence on GBL remains limited (Lam & Tse, 2022; Ting et al., 2019; Zou et al., 2018), especially regarding its impact on practical knowledge, confidence and student perceptions.

This study addresses these gaps by investigating four questions:

1. How effective is GBL in improving knowledge acquisition and practical application in SBS5221 *Piped Services*?

2. Does the GBL significantly enhance understanding of technical concepts such as pipe sizing and regulatory compliance?
3. How do students perceive the usability and engagement of the GBL tool?
4. What is its potential for application in other engineering modules?

The primary aim of this study is to evaluate the effectiveness of integrating GBL in enhancing engagement and learning outcomes. Pre- and post-game quiz results of the students were analysed to determine any statistical significance between the quiz scores. A structured questionnaire further assessed usability, engagement and perceived educational value.

By examining both learning performance and student perceptions, the study provides a comprehensive evaluation of GBL's applicability in technical education. It demonstrates how interactive simulation can bridge theory and practice, contributing empirical evidence to the use of digital game-based approaches in engineering education and informing future curriculum innovation.

Methods and Materials

The integration of GBL into the SBS5221 *Piped Services* module involved the development of an online mini-game with a total cost of HK\$50,000. The game was collaboratively designed by a professional game development company and the project team to align with the module's intended learning outcomes.

Game Design and Features

The mini-game simulated pipework design in a domestic building, providing an immersive learning environment. Students worked individually or in teams of up to four to address pipe sizing, material selection, water pressure, flow rate, and economic and sustainability considerations. Tasks the students included calculating water pressure, selecting appropriate materials and ensuring compliance with local standards, balancing technical performance with cost effectiveness and environmental sustainability.

Game Development Process

Development was collaborative and iterative, involving lecturers, student representatives and the game company. Initial meetings defined learning objectives and identified challenging topics to guide design. A prototype was created and pilot tested by five students, whose feedback led to improvements in interface design, task clarity and difficulty balance.

Subsequent refinements resolved technical issues and enhanced educational alignment while maintaining budget constraints. A Game Design Document (GDD) guided development, outlining game mechanics, objectives, player roles and the simulated domestic building environment. The final version presented realistic piping system challenges requiring students to apply technical, regulatory and sustainability considerations in system design (Figure 1).

Figure 1
Images of the Final Version of the Online Mini-Game



Evaluation Tools

Two tools were used to evaluate the effectiveness of the GBL.

(i) Pre- and Post-Game Quizzes

10 multiple-choice questions were administered before and after gameplay. The same questions were used in both tests, with solutions released only after the post-game quiz. The quiz assessed fundamental knowledge of cold water supply systems in domestic buildings in Hong Kong across four areas:

1. Pipe materials and fittings
2. Hydraulic principles (e.g., diameter, pressure and flow rate)
3. System design considerations (e.g., pressure limits, pressure loss)
4. Regulatory and professional knowledge

The questions evaluated both theoretical understanding and practical application aligned with the module's learning outcomes. Example questions include:

- “How does pipe diameter affect the flow rate in a cold water supply system?” (hydraulic principles)
- “Which government authority regulates the water supply in buildings in Hong Kong?” (regulatory knowledge)

(ii) Questionnaire Survey

A structured survey assessed students' perceptions of usability, engagement and educational effectiveness, as well as comparison with traditional teaching methods. It comprised four sections:

1. General Information – enrolment confirmation and prior familiarity with GBL.
2. Game Usability and Engagement – ease of navigation, interaction, engagement and visual design.
3. Educational Effectiveness – understanding of system design, clarity of technical concepts, problem-solving skills, realism and confidence in application.
4. Comparison to Traditional Learning – perceived effectiveness relative to lectures and labs, and willingness to have GBL in other subjects (e.g., HVAC, electrical systems).

Overall, the survey captured both experiential and learning dimensions of the GBL intervention and its potential for broader curriculum integration.

Results and Analysis

A total of 42 Year-3 students enrolled in the SBS5221 *Piped Services* module participated in the mini-game (about 20 minutes), completed both quizzes and responded to the questionnaire survey. Participants received a CPD certificate in recognition of their involvement.

Quiz Results

The quizzes quantitatively measured learning gains and showed an average improvement of 35.0%. Notable increases include:

- Pipework design considerations: 42.9% to 92.9% (+50.0%)
- Effect of system pressure on flow rate: 47.6% to 88.1% (+41%)
- Effect of pipe diameter on flow rate: 50.0% to 88.1% (+38.1%)

Detailed results are presented in Table 1.

Table 1

Quiz Results

Question	Concept Assessed	Pre-Game (%) Correct	Post-Game (%) Correct	Improvement (%)
1	Primary material for cold water pipes	52.4	81.0	28.6
2	Pipework design considerations	42.9	92.9	50.0
3	Water pressure limit for pipework	47.6	83.3	35.7
4	Regulatory authority for water supply	69.0	95.2	26.2
5	Effect of pipe diameter on flow rate	50.0	88.1	38.1
6	Measurement of water pressure	61.9	90.5	28.6
7	Pipe fittings for directional changes	54.8	88.1	33.3
8	Common causes of pipe bursts	50.0	85.7	35.7
9	Effect of system pressure on flow rate	47.6	88.1	40.5
10	Fittings for connecting different diameters	59.5	92.9	33.4
Average		53.6	88.6	35.0

Statistical Verification Using Paired-Samples *t*-Test

A paired-samples *t*-test was conducted to examine whether the improvement in quiz scores was statistically significant. As the same 42 students completed both quizzes, this test was appropriate. The null hypothesis (H_0) test was conducted to examine whether there was a significant difference between pre- and post-game mean scores. The alternative hypothesis (H_1) proposed that the post-game mean score would be significantly higher.

The mean pre-game score was 53.6% (5.36 out of 10), increasing to 88.6% (8.86 out of 10) in the post-game quiz, showing an average improvement of 35.0 percentage points (3.50 points). The paired-samples *t*-test yielded $t(41) = 8.84$, $p < 0.001$. At the 0.05 significance level (two-tailed), the critical value is $t_{critical} = 2.02$, the null hypothesis was rejected ($p < 0.05$). These results provide statistical evidence that the integration of GBL significantly improved students' understanding of piped services concepts.

Questionnaire Survey Results

The survey assessed usability, engagement and perceived learning impact. Prior familiarity with GBL varied (33.3% familiar; 38.1% not familiar).

A substantial majority (83.3%) found the game easy or very easy to navigate, indicating a user-friendly interface. Engagement levels were high, with 80.9% rating the game as engaging or very engaging. Regarding learning outcomes, 76.2% agreed that the game enhanced their understanding of technical concepts, and 83.3% reported increased confidence in applying their knowledge practically. In terms of realism, 76.2% considered the scenarios realistic or very realistic, supporting the game's effectiveness in linking theory with practice. When compared with traditional teaching methods, 80.9% preferred the game, and 90.5% supported extending GBL to other building services topics such as HVAC and electrical systems, highlighting its broader applicability within the curriculum.

Conclusion

The integration of GBL into the SBS5221 *Piped Services* module appears to be an effective pedagogical strategy. Statistically significant improvements in quiz scores, supported by positive student feedback, demonstrate that GBL enhances engagement, understanding and confidence in applying technical knowledge. To further strengthen its impact, future development should incorporate more advanced scenarios, improved navigation and enhanced graphical features. Expanding GBL to other modules, such as HVAC and electrical systems, may yield similar benefits. Overall, this study suggests that GBL has the potential to bridge theory and practice and represents a positive direction for innovation in engineering education.

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