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PAPER

Developing a Gamified Metaverse for Practical Learning at Sukhothai Thammathirat Open University

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ABSTRACT

The purposes of this study was to develop a metaverse based on the gamification concept for the practical learning management of students at Sukhothai Thammathirat Open University (STOU) and to study their practical learning outcomes. The research findings showed that the metaverse, based on the gamification concept and developed for this model, consists of five components: (1) the context of the university or institute; (2) input, including learners, learning objectives, instructors, support personnel, the learning environment, and supporting technologies; (3) the process, involving teacher and learner preparation, implementation of learning activities, and measurement and evaluation of learning outcomes; (4) output, comprising academic achievement and learner satisfaction; and (5) the feedback for improving the design of the teaching and learning system. Additionally, students who studied with this metaverse achieved practical learning outcomes higher than the specified criteria, with a result of 69.7%. Furthermore, the evaluation of practical learning outcomes from the gamified metaverse was determined by assessing two behavioral components: Process Efficiency (E1) and Outcome Efficiency (E2); this served as a quality assurance tool, supporting teaching and learning achievements.

KEYWORDS

human-centered computing, metaverse, gamification, practical learning management, open university

1 INTRODUCTION

The metaverse is a technology for creating virtual worlds that can blend virtual and real environments to create engaging experiences for participants. It is being developed to support the transition to a more integrated digital world. The metaverse is a persistent, multi-user environment that merges physical reality with digital virtuality. It represents a convergence of technologies that enable interactions with virtual environments, digital objects, and people, including virtual reality (VR) and augmented reality (AR) [1]–[3].

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Currently, the metaverse is a virtual space where people can socially interact through their avatars. It also helps reduce real-world limitations such as time and distance [4]. The metaverse provides a virtual environment that supports learning and teaching for numerous users and can integrate with traditional learning management systems (LMS). Furthermore, researchers note that these environments can combine self-study with learning through hybrid systems. For example, open-source platforms such as Moodle—a free LMS—can be integrated into a simulated web-based classroom to create an interactive learning space [5]. In addition, experts have examined the metaverse framework, including its structural design, functionality, learning activities, and instructional design that emphasizes nonverbal communication [6].

The term "metaverse applications" refers to presentation formats that vary depending on the purpose, technology usage, and target audience [7]. The metaverse is a broad term that encompasses all virtual worlds. A metaverse format is more specific, as it defines the characteristics of a particular metaverse, such as its focus on gaming, communication, or work [8]. This study focuses on using gamification to enhance the practical training for students in the Bachelor of Technology Program in Construction Management at Sukhothai Thammathirat Open University (STOU). This training involves quantity extraction from both two-dimensional (2D) drawings and virtual three-dimensional (3D) models of reinforced concrete structural components and architectural wall panel elements. These quantities are the primary data sources for building construction take-off and subsequent cost estimation.

1.1 The metaverse concept

The metaverse is defined as a networked, 3D virtual world where users can interact with each other through their own digital avatars. Key characteristics include its perpetual existence, cross-platform connectivity, a digital economy, and the integration of VR and AR technologies [9]. The metaverse was once seen as the next evolution of the internet, transforming working environments, learning styles, and society by generating more immersive and engaging digital experiences. Despite its technological and societal challenges, the metaverse's potential to transform the digital world has made it a topic of significant interest in the technological and business worlds [10]. For educational purposes, metaverse users can interact with others through virtual learning platforms. This enhanced interaction creates innovative, independent, and collaborative learning scenarios, enabling access to all available learning resources. The metaverse's systematic operation allows users to connect the real and virtual worlds seamlessly and timelessly [2].

The importance of the metaverse encompasses several aspects, directly impacting technology, society, and the economy, as follows:

1. Revolutionizing the digital experience: The metaverse has transformed the way we interact with digital technology, creating a more natural and engaging environment that reduces the limitations of communication over long distances [8].
2. Economic Impact: The metaverse opens up numerous new economic opportunities, including the creation of virtual markets, digital assets, and new business models. It is estimated that the metaverse could be worth as much as $5 trillion by 2030, equivalent to approximately 175 trillion Thai baht (based on a 2022 exchange rate of ~35 THB per USD) [11].
3. Transforming education and training: The metaverse has the potential to revolutionize education by enabling more interactive and engaging learning, allowing students to experience complex concepts in a more tangible way [12].

4. Healthcare Innovation: In the medical sector, the metaverse could be applied for medical training, telediagnostics, and virtual therapy. This has the potential to improve health outcomes and access to medical care [13].
5. Transforming Social Interactions: The metaverse is redefining social interaction, enabling more meaningful and engaging connections across geographic and cultural borders, potentially significantly impacting how relationships are built and maintained [14].
6. Driving Technological Innovation: The development of the metaverse is driving advancements in related technologies such as VR, AR, AI, and blockchain, which have far-reaching applications beyond the metaverse itself [11].

The development of the metaverse is a complex process aimed at creating a three-dimensional, interconnected virtual world through the integration of multiple technologies [11, 15]. Key components of the development include; (1) foundational technologies such as VR, AR, and 5G networks; (2) advanced platforms and software for content creation and management; (3) progressive hardware that supports immersive interactions; (4) a digital economy and society; (5) standards and protocols for interoperability between platforms; and (6) the application of artificial intelligence (AI) to enhance the efficiency and realism of users' experiences [8, 9]. These developments focus on creating a comprehensive digital ecosystem that can support unprecedented social, economic, and entertainment activities, aiming to transform the way humans interact with technology in the digital world [16].

1.2 The gamification concept

"Gamification" is the application of game principles, mechanics, and elements (e.g., points systems, badges, leaderboards, challenges, and storytelling) to non-game situations or activities to influence behavior, increase motivation, build engagement, and promote desired behaviors [17]. This definition covers three key points:

1. It is not just about using games. Gamification doesn't mean playing games directly or indirectly but rather focuses on using the "mechanics" and "elements" of games as tools [17].
2. The purpose of gamification is to influence behavior. The primary goal is to increase motivation, build engagement, and promote desired behaviors, such as improving performance, promoting learning, or building brand loyalty [17].
3. Gamification has a wide range of applications. It can be used in a variety of contexts, including everyday life, education, business, and society, such as using reward points in retail loyalty programs, using badges to display achievement levels in fitness apps, or using leaderboards to stimulate competition in online learning programs.

Three key concepts were used to design this study: 1) increasing motivation, 2) fostering participation, and 3) promoting desired behaviors. Furthermore, the application of leaderboards to stimulate competition in online learning programs will be discussed in the next topics. With the shift toward digital technology, gamification, or the concept of playing games, is becoming an integral part of people's lives. This concept has become part of various activities of users of various applications, including the use of the metaverse in digitally created environments [18]. Gamification is a modern approach to creating relationships between relevant users by supporting the application of virtual objects to the real world, enabling users to more effectively use virtual learning environments. With virtual instructor guidance, learners can be motivated to be active by being rewarded for their participation in daily activities or consistent participation in scheduled activities [19].

Gamification concepts are used in the Moodle LMS, a well-established e-learning platform for supporting and promoting student learning [20]. Students can measure their own academic achievement during their practical sessions by using the virtual learning environment via Moodle [21]. Collaborative learning has also been found to enhance student learning efficiency and stimulate deep learning, critical thinking within academic content design, and complex problem-solving [22]. Research has also found that combining established frameworks, theories, and models for online learning with synchronous communication can create interactive communities, as everyone can express themselves socially. Learners can gain knowledge and understanding through collaborative learning media, encompassing participation, discovery, explanation, and extension of what has been learned [23]. However, the benefits and importance of gamification include increasing motivation and engagement, making learners feel more entertained, challenged, and motivated to participate in various activities [24]. Moreover, it promotes learning and development, creates an engaging learning environment, and helps learners better recognize information and develop their skills [17, 25]. Other benefits of gamification include improving the performance of organizational personnel, promoting collaboration and motivating employees [26], creating more memorable user experiences, increasing satisfaction and brand loyalty, and ultimately promoting positive behaviors in areas such as health, environmental conservation, and social participation [27].

The development of gamification involves several key components, which are mechanisms and techniques derived from games to create engaging experiences. These components are specifically designed to encourage participation and stimulate desired behaviors [17, 26].

1. Mechanics: The rules and systems governing gameplay. Examples include:
   - 1.1 Points: Used to measure progress and achievement.
   - 1.2 Badges: Symbols awarded to represent an accomplishment or player status.
   - 1.3 Levels: Represent progress and mastery.
   - 1.4 Challenges: Missions or goals to be achieved.
   - 1.5 Leaderboards: Display player rankings to further encourage competition.
   - 1.6 Rewards: Incentives such as discounts, prizes, or special privileges.
2. Dynamics: The gameplay and interactions between players and the system. For example:
   - 2.1 Competition: Competing with other players.
   - 2.2 Collaboration: Working together as a team to achieve the mission.
   - 2.3 Storytelling: Using stories to create memorable experiences or impressions.
   - 2.4 Feedback: Providing players with feedback on their progress and results.
3. Aesthetics: "Aesthetics" refer to the visual, audio, and design elements, such as:
   - 3.1 Theme: The style and atmosphere of the gamification.
   - 3.2 Graphics: Illustrations, characters.
   - 3.3 Sound: Music, sound effects, and narration.

Developing effective gamification involves the following steps [17, 24]:

1. Define objectives. Clearly state the goals or achievements that the gamification needs to achieve, such as increasing sales, increasing engagement, or promoting learning.
2. Analyze the target audience. Study the audience's behavior, interests, and requirements to design a gamification that meets their specific needs.

3. Design mechanisms and components. Select mechanisms and components that are appropriate for the purpose and target audience, such as using points and badges to stimulate learning or using leaderboards to encourage competition.
4. Develop content and activities. Create engaging content, activities, and challenges that align with the objectives and connect to gamification mechanisms.
5. Test and improve. Test the gamification with the target audience, collect feedback, and make improvements to maximize its effectiveness.
6. Evaluate and track. Evaluate and track the gamification's results, such as sales, engagement, or satisfaction scores, to assess its success and guide future improvement.

There are several approaches to developing metaverse learning management systems based on gamification models, including the implementation of gamification in e-learning systems in higher education institutions. These approaches clarify the concepts and differences between gamification techniques and methods. Appropriate integration with e-learning systems can positively impact the learning process by increasing learner satisfaction, motivation, and engagement. This approach emphasizes clearly defined objectives, rules, techniques, and gameplay mechanisms, which influence learner transformation [28]. To successfully design an e-learning system by using gamification, it is essential to understand the core concepts of games, which include goal-oriented activities, reward mechanisms, and progress tracking. In e-learning systems, learners are instructed to perform certain activities to achieve desired goals. Therefore, progress tracking mechanisms and rewards are essential to increase learner motivation and engagement. Gamification supports the stages of e-learning system development, including analysis, design, development, implementation, and evaluation [29].

1.3 Concepts of learning design

Learning design based on the ADDIE principles [30] consists of the following five steps:

1. Analysis: This involves studying the learner groups, the goals and content of the metaverse, and the learners' problems and needs in using the metaverse.
2. Design: This involves defining learning objectives, the outline and sequence of content, learning activities, and the assessment criteria.
3. Development: This involves defining the details of each screen, the lesson title, course code, lesson content, work details, details of images, audio, and accompanying videos. This involves creating lesson presentations and testing lesson functionality. Once the metaverse lesson is developed, it is evaluated by experts for suitability and used for improvement. The metaverse is then piloted with students to determine its effectiveness. The metaverse is then revised and tested on the designated sample group to determine the effectiveness of the gamified metaverse. The metaverse's effectiveness is tested using the E1/E2 formula, as mentioned by [31], based on an 80/80 criterion.
4. Implementation: This involves pilot testing the gamified metaverse with a sample group, beginning with an explanation of the research objectives and research steps. Within the learning process through the metaverse, the sample group can freely access the metaverse at their desired time and place, with a usage period of 2 weeks.

5. Evaluation: The sample group completes a practical learning outcome assessment and a satisfaction assessment of the metaverse usage.

2 RESEARCH METHODOLOGY

The purpose of this study was to develop a metaverse based on the gamification concept for the practical learning management of students at STOU and to evaluate their practical learning outcomes.

For the design and development process of metaverse learning management based on the gamification model, as mentioned previously and based on the studies of [17, 26], the main elements for consideration in the design are as follows:

1. Mechanics are rules and systems that control the gameplay, consisting of (1) points (Points), (2) badges (Badges) to represent achievements or status, (3) levels (Levels) showing the progress of each level, (4) challenges (Challenges) as missions or goals that must be completed, (5) leaderboards (Leaderboards) showing the ranking of players, and (6) rewards (Rewards) as things given for motivation.
2. Dynamics are the gameplay and interactions between players and the system, such as (1) competition (Competition) with other players, (2) collaboration (Collaboration) working together as a team to achieve goals, (3) storytelling (Storytelling) using stories to create memorable experiences, and (4) feedback (Feedback) on progress and results.
3. "Aesthetics" refers to sensory elements, such as (1) the theme, which is the gamification style and atmosphere; (2) graphics; and (3) various visual elements, sound, music, sound effects, and narration.

And developing effective gamification follows the steps recommended by [17, 24]:

1. Define objectives. Clearly state the goals or achievements that the gamification is intended to accomplish.
2. Analyze the target audience. Studies their behavior, interests, and needs to design a gamification that meets their specific needs.
3. Design mechanisms and components. Select mechanisms and components appropriate for the objectives and target audience, such as using points and badges to stimulate learning or using leaderboards to encourage competition.
4. Develop content and activities. Create engaging content, activities, and challenges that align with learning objectives and connect with the gamification mechanisms.
5. Test and refine. Test the gamification with the target group, collect feedback, and make improvements to maximize its effectiveness and completeness, which includes compiling operational results to identify limitations.
6. Evaluate and monitor. Evaluate and monitor the results of gamification, such as participation or satisfaction scores, to assess its success and guide future improvements.

All of this leads to the determination of the research design for the development of a metaverse based on the concept of gamification for practical learning management for STOU students.

The research methodology is divided into three primary steps:

Step 1: Development and Evaluation of a Gamified Metaverse. This step focuses on developing and evaluating the effectiveness of a metaverse platform incorporating gamification principles for practical skills learning among STOU students. The process is divided into two parts: (1) Designing the conceptual model of the gamified metaverse, and (2) Developing the functional metaverse platform for student use.

Step 2: Evaluation of Learning Outcomes. This phase assesses the practical learning outcomes achieved by STOU students through their engagement with the gamified metaverse platform.

Step 3: Assessment of Student Satisfaction. This final phase measures student satisfaction with the overall experience of using the gamified metaverse for practical skills learning.

2.1 Step 1: Development and evaluation of a gamified metaverse

This step focuses on developing and evaluating the effectiveness of a metaverse platform incorporating gamification principles for practical skills learning among students at STOU. The process is divided into two parts:

Part 1. Designing the conceptual model of the gamified metaverse encompassing five components

1. The context of the university or institute.
2. Input, including learners, learning objectives, instructors, support personnel, the learning environment, and supporting technologies.
3. The process, involves teacher and learner preparation, implementation, and evaluation of learning activities.
4. Output, comprising academic achievement and learner satisfaction.
5. Feedback for improving the design of the teaching and learning system.

The initial phase in designing the conceptual model consisted of the research methodology outlined below:

- *Population and sample:* The group used to evaluate the suitability of the developed gamified metaverse model consisted of five experts who evaluated the initial model concept: experts in distance education, metaverse experts, educational technology experts, academic quantitative surveying (QS) experts, and content experts.
- *Research instruments:* The research instrument was a metaverse model based on gamification.
- *Data collection:* The researcher outlined the five steps for developing the gamified metaverse model as follows:
  Step 1: Studying relevant research documents from each country, in conjunction with the gamification concept.
  Step 2: Drafting and refining the gamification model.
  Step 3: Analyzing the content of the designated course based on the gamification concept.
  Step 4: Improving and designing the learning management components.
  Step 5: Developing a metaverse model based on the gamification concept for practical learning for Sukhothai Thammathirat Open University students in the Bachelor of Technology program in Construction Management (Continuing Education), School of Management Science.

- *Data Analysis:* The researcher analyzed the data using content analysis and focus group discussions. Data were recorded and triangulated to ensure research content validity. Experts participated in the focus group discussions and provided feedback from various perspectives to refine the gamified metaverse model to align with the research project objectives.

Part 2. Development of the gamified metaverse model for practical learning for STOU students. The metaverse development process consists of four steps:

Step 1: Integrating the conceptual model of the gamified metaverse into the development of a functional metaverse platform for student use.
Step 2: Developing the metaverse, including the front-end system, back-end system, and metaverse platform.
Step 3: Testing the gamified metaverse with target students.
Step 4: Revising the gamified metaverse based on user feedback to align with the research project objectives.

- *Population and Sample:* The minimum sample size for testing the developed gamified metaverse was 30 students who were familiar with the process of quantity take-off in the construction estimation course.
- *The research instrument:* The research instrument consisted of a questionnaire that was tested for content validity by using the Index of Item Objective Congruence (IOC) and for reliability using Cronbach's alpha, which measured the reliability of the questionnaire based on the internal consistency of the questions.
- *Data Collection and Analysis:* Using descriptive and inferential statistical analysis, the researchers analyzed the results of the student metaverse test based on the concept of gamification, recorded in the system, to align with the research project objectives.

2.2 Step 2: Evaluation of practical learning outcomes from the gamified metaverse

This step involved studying the practical learning outcomes of students who used the gamified metaverse. This included evaluating their performance; thus, the workflow was defined as follows:

- *Population:* The population consisted of undergraduate students enrolled in the first semester of the 2023 academic year, course 31308: Theory and Practice of Quantity Surveying and Construction Cost Estimating, Bachelor of Technology Program, Construction Management, School of Management Science, STOU. A simple random sampling method was applied, with a minimum sample size of 30 students.
- *Research Instruments:* A practical learning outcome assessment form was used, in which a score of 70% or higher was required to pass the post-test performance criterion (E2).
- *Data Collection and Analysis:* The analysis of practical learning outcomes for students using the metaverse involved comparing their scores to determine if they exceeded the specified criteria. The process was as follows:
  1. Coordinating with the course chairperson for 31308, Theory and Practice of Quantity Surveying and Construction Cost Estimation, to obtain the details of the sample students.

2. Briefing the sample group of STOU students on the details of the steps before, during, and after learning with the gamified metaverse.
3. Instructing students to take a test after completing the gamified metaverse to determine whether their practical learning outcomes exceeded the specified criteria.

2.3 Step 3: Assessment of student satisfaction with the gamified metaverse

The final step involved assessing student satisfaction with the metaverse. This included their satisfaction with the overall experience after using the gamified metaverse for their practical skills learning. For the purposes of this article, the authors have omitted a discussion of the analysis.

3 RESEARCH FINDINGS

This section presents the results of the data analysis regarding the development of the gamified metaverse for practical learning management of STOU students. The researcher has organized the analysis results into three main sections:

Section 1: Results of Data Analysis Evaluating the Effectiveness of the Metaverse

This section presents the results of data analysis evaluating the effectiveness of the metaverse based on gamification concepts for practical learning management for STOU students. The data analysis results are presented in two sub-sections:

- Sub-Section 1) Initial development of the gamified metaverse model for practical learning management for a target group of students, based on a review by a focus group of five experts.
- Sub-Section 2) Full development of the gamified metaverse for the practical learning management of STOU students.

Section 2: Results of Data Analysis on Practical Learning Outcomes

This section covers the results of data analysis on practical learning outcomes using the metaverse based on gamification concepts for practical learning management for STOU students. The data analysis results are presented in the evaluation of STOU students' practical learning outcomes after using the gamified metaverse.

Section 3: Results of the Data Analysis on Students' Satisfaction

This section presents the results of the data analysis on students' satisfaction with the gamified metaverse.

3.1 Section 1: Results of data analysis evaluating the effectiveness of the metaverse

From the review by a focus group of the five *experts—consisting* of 1) metaverse experts, 2) educational technology experts, 3) experts in distance education, 4) academic quantitative surveying (QS) experts, and 5) content *experts—the* details are shown in Table 1. All five experts evaluated the metaverse format based on the gamification concept as appropriate for practical learning for STOU students.

Table 1. Refined recommendations from an expert focus group on enhancing a gamified metaverse for practical learning at STOU

	Detail
1. The context of the university or institute	University or institutional contextual factors and environments, both internal and external, affect an institution's ability to achieve its goals.
2. INPUT	**1.** Learners **1.1** Before analyzing learners, it is essential to first analyze their needs, problems, and desired conditions, including the content of course materials related to their practical learning. **1.2** In analyzing learner readiness, the analysis should cover learners' knowledge and skills in information technology, communication and interaction skills, knowledge, experience, and competencies required for distance learning, practical training foundations, metaverse use, and gamification capabilities, as well as the readiness of devices (PC, Notebook, Tablet, or Smartphone) and internet access for learning, in accordance with the requirements for the learning environment and technologies supporting learning. **1.3** Learners must be responsible, enthusiastic, self-disciplined, and committed to learning. Learners can learn anywhere and anytime. Defining learner roles or characteristics should include preparing for learning with the gamified metaverse and taking responsibility for every step of the learning process by completing scheduled activities.
	2. Defining Learning Objectives/Defining Learning Outcomes Learning outcomes determine teaching and learning activities, foster advanced learning skills for practical learning, and link learners to the course's learning outcomes and those expected for necessary additional content. These outcomes include content knowledge and process, specifying what learners should know by the end of each assigned module. Furthermore, behavioral objectives outline instruction, help plan instruction, and guide the assessment of learners and instructional effectiveness. These objectives require the use of measurement and evaluation tools.
	3. Teachers and Support Personnel **3.1** Instructors Instructors must have knowledge and understanding of technologies that support learning and learners, their roles, responsibilities, knowledge and skills in using the gamified metaverse. They must also possess practical training skills, including course management, technical, and social skills. This includes lesson planning and lesson design that aligns with the media being applied. Content presentation must include presenting the core content, establishing learning guidelines, monitoring student progress, and providing feedback. Instructors must create an environment that facilitates and supports student self-learning and encourages continuous collaborative activities. **3.2** Support Personnel Support personnel should include instructional designers who will define the learning path and experience using technology for students. Technical staff should possess knowledge and skills in using the gamified metaverse. The support staff must prepare the entire system before students start learning, working with instructors to prepare lessons according to the specified modules, granting students access to classes, and reporting attendance to instructors within the designated timeframe. They also facilitate and resolve issues when students are unable to access the relevant system. They also serve as teaching assistants and support instructors in practical training.
	4. Establishing a Learning Environment and Supporting Technology **4.1** This stage involves studying the needs and readiness of devices and technologies that support learners' learning in the gamified metaverse. This involves establishing the basic standards and specifications of devices that can suitably support learning in the metaverse based on the concept of gamification and technologies that support learning, as well as the competencies and abilities of learners within the metaverse. This takes into account the limitations and features of devices and technologies that support learners' learning when connected to the internet. Learner analysis includes learners' prior knowledge and their computer skills. **4.2** The environment should facilitate learning and practicing in a challenging virtual environment and using gamification capabilities. Each lesson should include setting learning goals or activities designed to achieve them according to the criteria set by the instructor. **4.3** The environment should consider the design of the user interface, including the use of theme colors, fonts, screen layout, and user experience. This should include a sequential and easily understandable design process.
	5. Metaverse-Based Learning Media Metaverse-based learning media based on gamification concepts are designed to present content and activities aligned with learning outcomes. Learners can choose their own learning materials and are encouraged in their learning intentions through game elements. This includes rewards in the form of accumulated points and leaderboards for collaborative interaction in the virtual world and continuous self-learning. Instructional media is made available periodically or via shortcut buttons. Furthermore, the learning media may include infographics illustrating the steps for use in line with the lesson content, taking into account the virtual environment, teaching time, and learner behavior.

(Continued)

Table 1. Refined recommendations from an expert focus group on enhancing a gamified metaverse for practical learning at STOU *(Continued)*

Detail	
3. PROCESS	Implementation of Teaching and Learning Activities
	Step 1: Teacher and Student Preparation To prepare for the lesson, teachers and students must have a clear understanding of the learning objectives, teaching methods, and learning activities using the gamified metaverse. An orientation file, a short video clip, and a learning guide are provided to the target group of students to give them a visual overview of the entire process of using the gamified metaverse, including modules or activity bases for collaborative interaction in the virtual world. The guidelines and rules, including accumulated points and leaderboards, are outlined in accordance with the concept of gamification. This preparation covers the objectives, content, and teaching methods, as well as the availability of devices and technologies that support learning, including internet connectivity.
	Step 2: Implementation of Learning Activities Details are provided to align the instructor's learning management with the learner's learning process. These details cover the format and characteristics of the metaverse practice based on the gamification concept, in line with the previously outlined preparation steps.
	Step 3: Measurement and Evaluation To measure and evaluate the learner's practical learning outcomes against specified criteria, the assessment will be based on scores from participation in activities within the specified modules and on post-tests. This evaluates the learner's knowledge after completing the content. Furthermore, the assessment will evaluate learner satisfaction with the metaverse model based on the gamification concept.
4. OUTPUT	**1.** Academic Achievement This assessment evaluates learners' content knowledge after completing the content and participating in the assigned activities. It aims to assess learners' academic achievement through the use of the metaverse model based on the gamification concept. Furthermore, practical outcomes include skill development from practical training, collaboration, and problem-solving through gamification. This assessment also covers desired learning behaviors and advanced learning skills.
	2. Learner Satisfaction with the Metaverse Model Based on Gamification Concepts This study evaluates the effectiveness of the teaching model by determining learner satisfaction with the metaverse model based on gamification concepts.
5. FEEDBACK	Feedback for Improvement Feedback for improving the design of the instructional system will focus on the input and process stages to better achieve the specified learning outcomes.

The framework for enhancing a gamified metaverse for practical learning for STOU students is detailed in Figure 1.

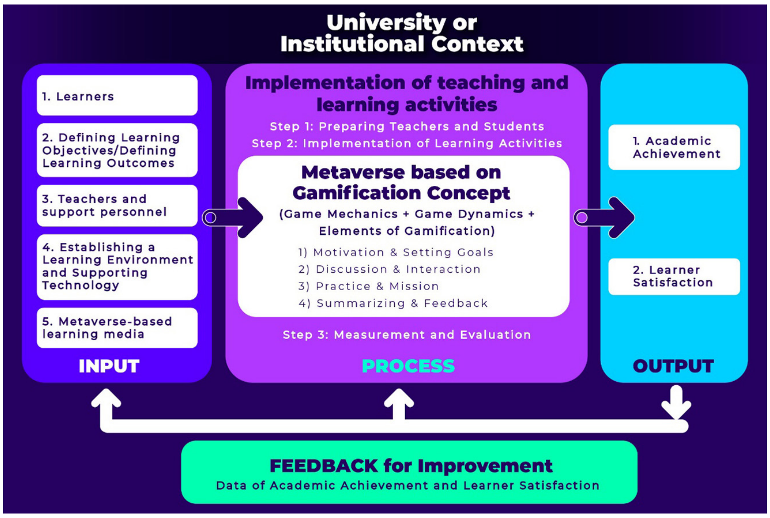

Fig. 1. The framework for enhancing a gamified metaverse for STOU student practical learning

3.2 Section 2: Development of the gamified metaverse model for STOU student practical learning

The development of the gamified metaverse involves several key components as mentioned before, which are mechanisms and techniques derived from games to create engaging experiences. These components are specifically designed to encourage participation and stimulate desired behaviors, as noted in the studies of [17, 26].

This gamified metaverse for STOU student practical learning focuses primarily on the take-off of construction material quantities for specific structural and architectural components. The model's development is composed of three main elements:

1. Mechanics: The rules and systems governing gameplay, such as points, badges, levels, challenges (missions or goals), leaderboards, and rewards.
2. Dynamics: The gameplay and interactions between players and the system, such as competition, storytelling, and feedback. Competition is created by ranking scores on the leaderboard, while feedback provides players with information on their progress and results.
3. Aesthetics: Refers to the visual, audio, and design elements, such as a theme and graphics that are consistent with the lesson content.

To monitor progress during students' practical learning, the system features a progress-tracking mechanism to display the learner's mission status. Each mission is accompanied by a checkbox, allowing learners to visually monitor which tasks they have completed by themselves. The reward mechanism is activated upon submission of in-game answers. When the learner clicks the "Submit" button, the system provides immediate feedback, displaying the score achieved on the questions along with a corresponding grade for the practical learning component. Learners acquire practical skills within a simulated professional environment in the gamified metaverse. To complete each module, learners must accomplish four missions focused on the take-off of construction material quantities for specific structural and architectural components, including:

1. Calculation of concrete volume for B5/B7 beams.
2. Calculation of reinforcing steel quantity for B5/B7 beams.
3. Calculation of formwork quantity for B5/B7 beams.
4. Calculation of wall area (W1 & W8) in architectural work.

As detailed in the Appendices, an evaluation of the gamified metaverse was conducted with a target group of 23 STOU students. The evaluation found that students achieved an average performance score of 69.7%. For the practical component, students achieved scores ranging from 7 to 8 on a 10-point scale. According to the chairman of the course "31308 Theory and Practice of Quantity Survey and Estimation of Construction Work," a score of 70% or higher meets the performance criterion for the post-study test (E2) (refer to Table 2). Additionally, the overall satisfaction with the metaverse was rated as high.

Table 2. Frequency distribution of post-study test (E2) scores for 23 STOU students

Performance Score	Frequency	Valid Percent	Cumulative Percent
6	7	21.20	21.20
7	13	39.40	60.60
8	10	30.30	90.90
9	3	9.10	100

3.3 Section 3: Evaluation of practical learning outcomes from the gamified metaverse

The efficiency of the metaverse-based learning environment was determined by assessing two behavioral components:

Process Efficiency (E1) and Outcome Efficiency (E2). The benchmark for effectiveness was set at the 70/70 E1/E2 ratio. As referenced by the study of [31], the effectiveness of instructional media or packages refers to the extent to which learners exhibit desirable behavioral changes as expected by the instructor. Process Efficiency (E1) was measured based on the average scores from 13 sequential, hands-on tasks. These tasks required students to calculate the required volume of concrete for beams, the quantity of steel reinforcement, formwork dimensions, and wall surface area, with performance evaluated against pre-defined accuracy criteria. Outcome Efficiency (E2) was assessed through a 10-item post-test administered after the metaverse activities. A passing threshold was set at 70% (7 out of 10 items correct). The results indicated that students who completed all designated tasks achieved the target efficiency of 70/70 (E1/E2). Furthermore, the collected data for Process Efficiency (E1) and Outcome Efficiency (E2) were analyzed to determine their descriptive statistics, specifically the mean, standard deviation (SD), and the minimum and maximum values (Table 3).

Table 3. Descriptive statistics for Process Efficiency (E1) and Outcome Efficiency (E2)

Mark (E2)		***Mark (E1)***	
Mean	**7.27**	**Mean**	**6424.24**
Standard Error	0.15854886	Standard Error	341.3717399
Median	7	Median	6800
Mode	7	Mode	7700
Standard Deviation	0.91079386	**Standard Deviation**	1961.031346
Sample Variance	0.829545455	Sample Variance	3845643.939
Kurtosis	-0.676730489	Kurtosis	-0.362543808
Skewness	0.203044306	Skewness	-0.256843214
Range	3	Range	7800
Minimum	6	**Minimum**	2400
Maximum	9	**Maximum**	10200
Sum	240	Sum	212000
Count	33	Count	33

The frequency and descriptive statistics for gender are presented in Table 4.

Table 4. The frequency distribution and descriptive statistics for gender

		Gender			
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	**Male**	**27**	**81.8**	81.8	81.8
	Female	**6**	**18.2**	18.2	100.0
	Total	33	100.0	100.0	

The frequency analysis revealed that the sample of students (N = 33) consisted of 27 males (81.8%) and 6 females (18.2%). For the Process Efficiency (E1) scores, the analysis of the 33 students' performance across the 13 stages revealed a mean of 6424.24 and a standard deviation of 1961.03. The scores ranged from 2400 to 10200 (range = 7800), with a skewness of –0.257. Each unique score value appeared with a frequency of one or two (3.03% – 6.06%), as depicted in Figure 2. The Process Efficiency (E1)/Outcome Efficiency (E2) $\left(\frac{E1}{E2}\right)$ as the efficiency criterion was defined as the successful completion of all 13 E1 stages and scoring a minimum of 70% on the E2 post-test. Based on this standard, 23 out of 33 students (69.7%) achieved the target efficiency. An analysis of the E1/E2 ratio for all samples of students revealed a mean of 897.10 and a standard deviation of 305.29. The values ranged from 342.86 to 1457.14 (range = 1114.29) with a skewness of 0.11. The distribution of these values is shown in Figures 3a and 3b.

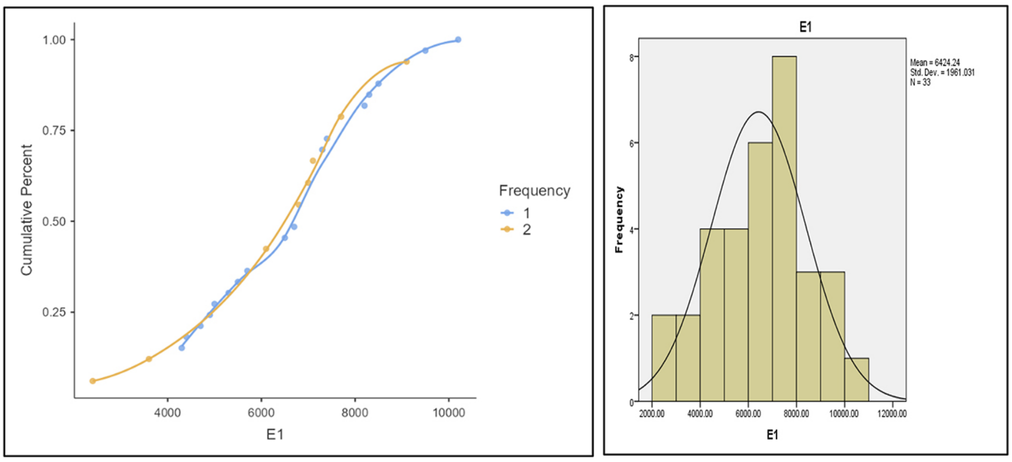

Fig. 2. Frequency and cumulative percentage of Process Efficiency (E1) scores for 33 students across 13 stages

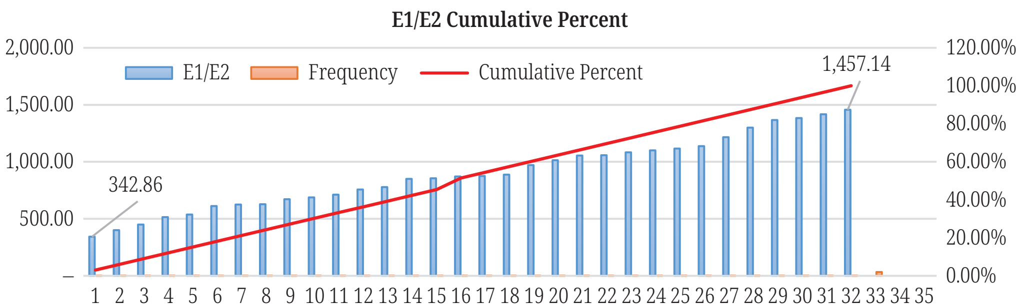

Fig. 3a. Cumulative percent of $\left(\frac{E1}{E2}\right)$ with values ranging from 342.86 to 1457.14 (Range = 1114.29)

E1/E2	
Mean	897.1019721
Standard Error	53.14535072
Median	871.4285714
Mode	871.4285714
Standard Deviation	305.2967966
Sample Variance	93206.13401
Kurtosis	-0.787388127
Skewness	0.119864702
Range	1114.285714
Minimum	342.8571429
Maximum	1457.142857
Sum	29604.36508
Count	**33**

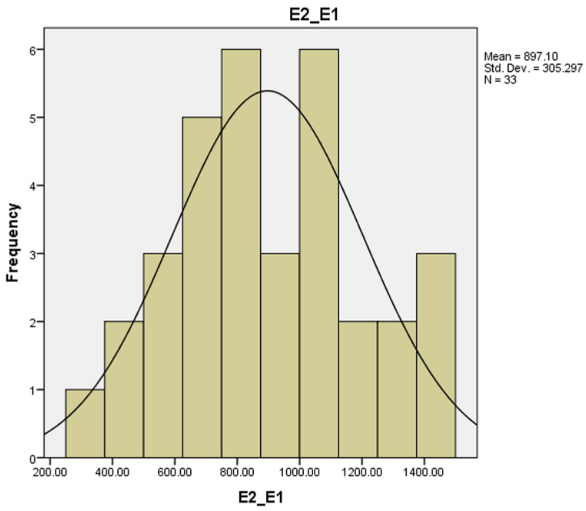

Fig. 3b. Frequency and descriptive statistics of $\left(\frac{E1}{E2}\right)$ for 33 students

From the test of process efficiency (E1) and outcome efficiency (E2) is crucial for evaluating the practical learning outcomes of the gamified metaverse by serving as a quality assurance tool for instructional media before mass production, aiding in teaching and learning achievement, helping to improve content for learners, and enhancing student's learning habits, as mentioned by [31].

4 DISCUSSION

The development of a gamified metaverse was fundamentally based on the concept of gamification, as mentioned by [17]. For this study, the gamified metaverse was primarily defined using concepts from the metaverse literature, as cited by [2, 8–9]. The study also drew upon [12], particularly concerning the application of these concepts in transforming education and training. This study of the gamified metaverse was consistent with the study of [18]. It was prepared for practical learning for STOU students, and the preliminary model was meticulously evaluated by five experts and found to be most appropriate overall. In accordance with the highest-rated items, including input component, the learners' aspect requires responsibility, enthusiasm, self-discipline, and dedication in self-learning. With the setting of learning objectives and outcomes, as well as the instructional activities, support personnel came up with an instructional designer who defines the learning path and experience with this particular technology. This is consistent with the suggestions of [17, 26]. While the arrangement of the learning environment and supporting technology depends on a study of the learners' needs and equipment readiness, the process component includes the highest-rated activities. These are Step 1, the preparation of teachers and learners, and Step 3, the measurement and evaluation of outcomes. The Output component comprises academic achievement and learner satisfaction with the gamified metaverse model, and the Feedback component is for improving the design of the teaching and learning system. This approach is based on the fundamental concept of ADDIE principles aligned with the instructional systems mentioned by [30]. This is consistent with the finding that the success of the metaverse depends on the readiness of the learners and the arrangement of their learning environment with supporting technology, as cited in [10, 15].

This development focuses on creating a comprehensive digital ecosystem that combines entertainment activities with a challenging learning environment. Through human interaction, the development is dedicated to supporting and promoting STOU students' learning with technology in the digital world, consistent with studies by [16, 20]. Secondly, the development of the gamified metaverse model for student practical learning comprises three main elements: (1) mechanics, (2) dynamics, and (3) aesthetics, as cited by [17, 26]. The targeted mission was the aspect of quantity take-off per construction specifications, which was evaluated among 23 STOU students. They achieved an average performance score of 69.7% for the practical component, with scores ranging from 7 to 8 on a 10-point scale. This performance was reasonably accepted, especially for the post-study test (E2), "the Outcome Efficiency." Lastly, the evaluation of practical learning outcomes from the gamified metaverse was determined by assessing two behavioral components: process efficiency (E1) and outcome efficiency (E2). These components serve as a quality assurance tool for supporting teaching and learning. The effectiveness of the instructional materials was evaluated through pre- and post-tests, consistent with the study of [31]. Even if the obtained values met the established criteria (70/70), in principle, they are still considered flawed. The calculated E1/E2 values should be close to the established criteria and be sufficiently high. If the E1/E2 values are only 70/70, the instructional media may need improvement, as the scores are not yet at a satisfactory level for the content, as noted by [31]. Therefore, the sample group should be increased, the content should be adjusted to include more details and complexity, and the activities should be made more challenging.

5 CONCLUSION

The results of the data analysis on the effectiveness of the gamified metaverse were derived from an expert focus group. This group recommended five components for enhancing learning practices at Sukhothai Thammathirat Open University:

1. The context of the university or institute.
2. Input, which included the learners' aspect, learning objectives/outcomes, teachers and support personnel, learning environment and supporting technology, and metaverse-based learning media.
3. The process, involves teacher and learner preparation, implementation of learning activities, and measurement and evaluation of learning outcomes.
4. Output, comprising academic achievement and learner satisfaction.
5. Feedback for improving the design of the teaching and learning system.

The development of the gamified metaverse model for STOU student practical learning was composed of three main elements: (1) Mechanics: the rules and systems governing gameplay; (2) Dynamics: the gameplay and interactions between players and the system; and (3) Aesthetics: the visual, audio, and design elements. The targeted mission, which involved the take-off of construction material quantities for specific structural and architectural components, was evaluated among 23 STOU students. They achieved an average performance score of 69.7% and approximately 70% overall satisfaction.

Finally, the evaluation of practical learning outcomes from the gamified metaverse was determined by assessing two behavioral components: process efficiency (E1) and outcome efficiency (E2). These components served as a quality assurance tool, supporting teaching and learning achievement, improving learners' content, and enhancing student's learning habits. Consequently, using the gamified metaverse in this study can efficiently enhance practical training for students in the Bachelor of Technology Program in Construction Management at Sukhothai Thammathirat Open University.

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8 APPENDICES

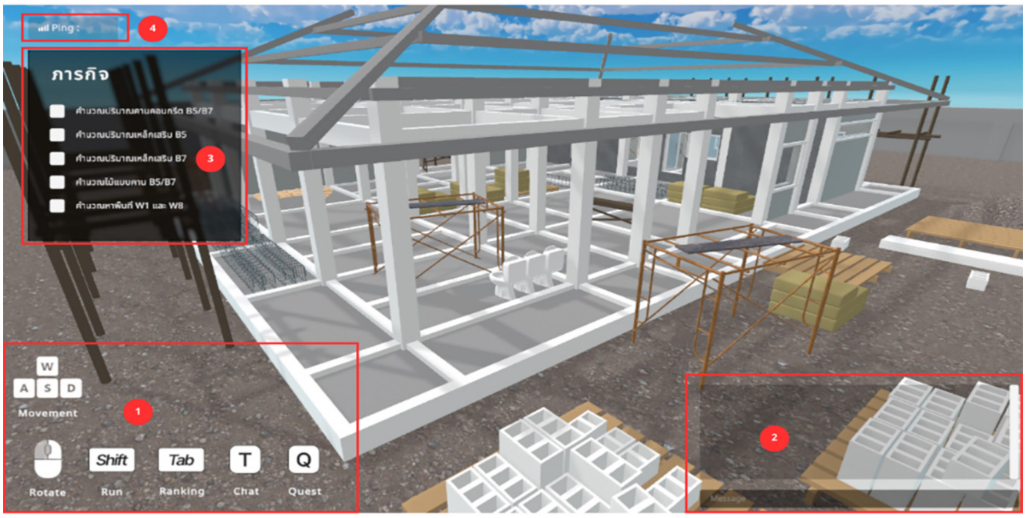

Fig. A1. Illustrates the user interface, in-game controls, and missions

Fig. A2. Depicts the process of calculating concrete volume for beams B5 and B7 in-game

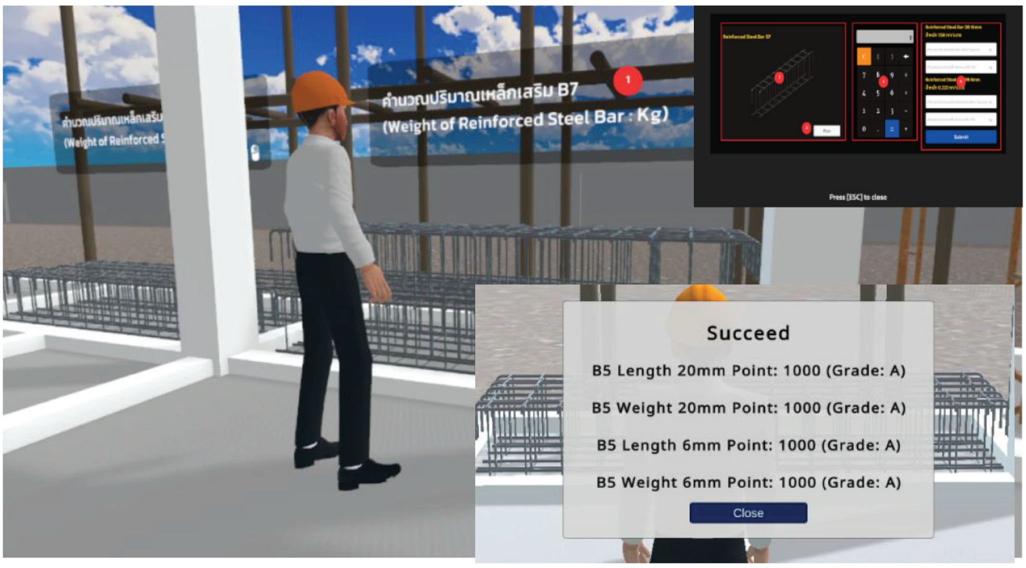

Fig. A3. Depicts the process of calculating reinforcement weight for beam B7 in-game

Fig. A4. Depicts the calculation of wall area for W1 and W8

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