From Classroom to Metaverse: A Study on Gamified Constructivist Teaching in Higher Education

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From Classroom to Metaverse: A Study on Gamified Constructivist Teaching in Higher Education

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Abstract. In the rapidly evolving educational landscape, the integration of metaverse and gamification is emerging as a revolutionary approach. This paper presents the Gamified Constructivist Teaching in the Metaverse (GCTM) framework, aiming to enhance engagement and satisfaction in the computer science education domain. Implemented in two engineering classes using the metaverse platform, the GCTM model, with its unique combination of game world design, rule design, roleplay, mission assignments, and evaluation, demonstrated promising results in enhancing student-lecturer interactions. Feedback indicated a stronger sense of belonging among students in the virtual environment compared to conventional platforms like ZOOM or MS Teams. The findings underscore the potential of GCTM in transforming the educational experience, suggesting a significant stride towards a more interactive and learner-centric approach in the metaverse-driven educational era.

Keywords: Metaverse · Eduverse · Constructivism · Online teaching

1 Introduction

The COVID-19 pandemic has precipitated unforeseen and sustained consequences on the system of higher education [1]. Over the course of several recent semesters, a pervasive shift has occurred from traditional face-to-face (F2F) instructional delivery to a synchronous online mode. This transformation has catalyzed the development and utilization of an abundance of multimedia resources, including numerous videos and online materials tailored for autonomous student learning [2].

The exigencies of the pandemic have compelled students to adapt to new paradigms of learning, which predominantly manifest in online or hybrid formats, as physical attendance became a logistical impossibility in many instances. Within our institutional

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context in 2021, we implemented a synchronous hybrid model of instruction. This adaptation was met with varied levels of student engagement. For instance, when presented with the opportunity to attend classes in person, only a minority of 13.5% of the student body participated in all the face-to-face sessions.

A closer examination reveals a more disconcerting trend within specific academic units, such as the Department of Computing. As depicted in Table 1, only 5.6% of students in this department attended all the face-to-face classes. Furthermore, a subset comprising 4.9% of the students opted to engage with class recordings rather than participating in real-time instruction for more than half of the classes. This observation warrants further investigation into the underlying factors that may be influencing these patterns, potentially offering insights into the broader challenges and opportunities presented by this seismic shift in educational delivery.

Table 1. A Survey of Class Modality at Polyu in 2021

Class Modality	COMP N = 142	PolyU N = 3457
I attended all my classes f2f	5.6%	13.5%
I attended more than half of my classes f2f	18.3%	24.0%
I attended about half of my classes f2f	17.6%	16.8%
I attended more than half of my classes online	23.9%	25.1%
I attended all my classes online	28.9%	16.7%
I watched class recording instead of attending classes in real time for more than half of my classes	4.9%	2.4%

COMP = Students in Department of Computing
PolyU = Students in The Hong Kong Polytechnic University

In a subsequent survey conducted in 2022, the evolving preferences and behaviors of students with respect to instructional delivery were further elucidated. According to the data presented in Table 2, a mere 15% of the students surveyed expressed a preference for face-to-face class attendance. Within the specific disciplines surveyed, this preference manifested in 209 students in the Computer Science department (COMP) and 62 students in the Electrical and Information Engineering department (EIE).

This marked decline in preference for traditional classroom attendance reflects a potential paradigm shift in educational expectations and engagement. These findings invite further scholarly exploration into the underlying causes and potential implications of this trend, with particular attention to how institutional strategies and pedagogical practices must evolve in response to these changing dynamics. The implementation of online teaching modalities, such as ZOOM or Microsoft Teams, offers distinct advantages in terms of class management, encompassing functionalities like lesson recording, account administration, and security measures. While ZOOM is architected primarily for webinars [3], Microsoft Teams is oriented towards meetings [4]. Both platforms facilitate a form of passive learning, catering well to this mode of educational engagement.

Table 2. A Survey of Preferred Class Modality at Polyu in 2022

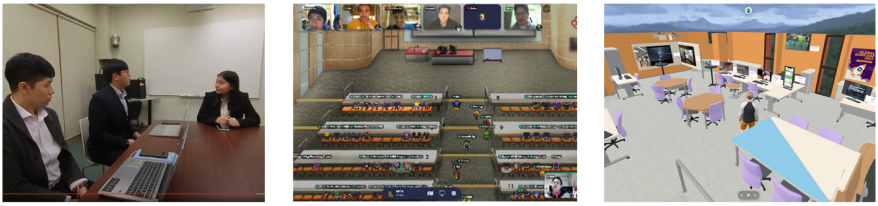
Class Modality	COMP N = 142	PolyU N = 3457
Entirely face-to-face	32(15.4%)	10(16.1%)
Minimal use of the Web, mostly held in face-to-face format	21(10.1%)	12(19.4%)
An equal mix of face-to-face and web content	68(32.7%)	19(30.6%)
Extensive use of the Web, but still some face-to-face class time	51(24.5%)	16(25.8%)
Entirely online with no face-to-face time	36(17.3%)	5(8.1%)

COMP = Year 3 students in Department of Computing
EIE = Year 4 students in Department of Electronic and Information Engineering

However, an intriguing and somewhat concerning observation was made in the transition to online education. It appears that the pandemic-induced shift to online learning has fostered a more passive approach among many students. Common behavioral indicators include reluctance to activate video cameras or engage in discussion with classmates, leading to a noticeable absence of peer-to-peer interaction and a diminished sense of community and belonging.

This trend is particularly disconcerting given the overarching philosophy that university education extends beyond mere knowledge transfer. Rather, the role of higher education is to cultivate active, lifelong learners capable of addressing real-world problems [5]. This mission inherently involves nurturing soft skills and fostering teamwork, capacities that can be inhibited if active and peer-to-peer learning is lacking [6, 7]. A deficit in these areas may impede the development of essential problem-solving abilities and undercut efforts to strengthen the core component of learn-to-learn skills.

In response to the aforementioned challenges, we initiated different innovative approach in 2020, leveraging mixed reality and the metaverse technologies to stimulate a more active learning stance among students during online instruction and various activities (see Fig. 1) [8–12]. We have endeavored to provide immersive and interactive experiences for the students. This paper elucidates three fundamental concepts underpinning our implementation. Firstly, it explores the methodologies employed to interconnect diverse technologies for the provision of education within the metaverse, a virtualized environment. Secondly, it examines strategies to engage students by employing gamification techniques and constructive teaching methods, thereby fostering collaboration, motivation, and active participation in the learning process. Thirdly, it investigates the integration of knowledge through the utilization of an interactive knowledge graph model, a sophisticated structure that links related information in a networked fashion.



(a) 360-degree video to understand the working situation in IT industry (Link)

(b) Teaching in Gather.Town, a 2D spatial video conferencing platform in a large class (N>200) (Link)

(c) Teaching in Spatial.io,a 3D spatial video conferencing platform in a small class (N<15) (Link)

Fig. 1. Applying different mixed reality and the metaverse technologies in teaching

2 Literature Review

2.1 Metaverse and Educational Metaverse

The concept of the Metaverse is subject to varying interpretations, reflecting its multifaceted nature. Jon Radoff has introduced an onion structure to represent the Metaverse, employing a seven-layer model to articulate the diverse requirements from infrastructure to user experience within this virtual realm [13]. Similarly, Brian Jackson of InfoTech Research Group has advanced a union structure for the Metaverse, positing it as a technological convergence [14]. Numerous analytics and market research firms have also contributed various infographics, delineating the key players and stakeholders within the Metaverse ecosystem [15]. Despite these attempts at definition, the complexity and multifarious nature of these representations may render them somewhat inaccessible for educators aiming to integrate metaverse technologies into their teaching practice. Further complicating matters, the broad scope and rapid evolution of the Metaverse leave us without a comprehensive understanding of how distinct technologies operate within education, why they are necessary, and how they may evolve in the near future [16].

2.2 Gamification and Constructive Teaching

Gamification refers to the application of game-related elements within non-gaming environments, seeking to harness the intrinsic motivators that games offer [17]. Contrasted with traditional learning approaches, such as lecture-based teaching, gamification presents several advantages that align with contemporary educational goals. These benefits include: 1) the enhancement of student motivation through interactive and competitive elements; 2) the potential for improved knowledge retention, as students often engage more deeply with gamified content; 3) the introduction of social mechanisms, such as badges, points, or leaderboards, which can foster a sense of community and achievement, thereby engaging students on a more profound level [18, 19]. The adoption of gamification within the metaverse opens new avenues for exploration, extending the boundaries of traditional learning and creating an enriched, dynamic educational landscape.

Constructivism is a pedagogical theory positing that learners actively construct knowledge rather than merely absorbing information in a passive manner. Through experiencing the world and reflecting on these experiences, individuals craft their own representations and integrate new information with their pre-existing knowledge structures [20, 21]. This constructivist approach has been employed in our service-learning projects, wherein students are immersed in real-world problems. The learning process involves understanding the problem, analyzing technical solutions, engaging with stakeholders, and devising solutions to authentic challenges [22]. We have observed that the constructivist approach is particularly resonant with engineering students and are thus motivated to explore its extension from the physical to the virtual world.

An instructive application of constructivist principles is embodied in the 5E Model, which was developed by the Biological Sciences Curriculum Study (BSCS) in 1987. The 5E Model is oriented toward promoting collaborative and active learning, with the goal of encouraging students to be engaged and social participants in their educational journey. By actively engaging with and reflecting on educational activities, students are facilitated in reconciling new knowledge with their existing conceptual frameworks. Several educational movements, such as inquiry-based learning, active learning, experiential learning, discovery learning, and knowledge building, are recognized as variations on the constructivist theme. According to subject matter expert Beverlee Jobrack, these methodologies are unified in their commitment to fostering an enriched, active engagement with learning content [23–25]. In synthesizing these principles with the emerging possibilities of the virtual world, the stage is set for a vibrant expansion of pedagogical innovation and effectiveness.

2.3 Connection with the Domain Knowledge

The knowledge graph is also considered a solution to reduce information overload during browsing domain knowledge for new knowledge users [26]. Hao et al. used a knowledge map and social network analysis to navigate the knowledge users. They used a Boolean value to connect each knowledge node, ignoring the similarity between domain knowledge. Janowicz et al. adapted a knowledge graph to visualise environmental knowledge and spatial data to a 2D knowledge graph [27]. Lin et al. try to turn medical expertise into a knowledge graph by representing knowledge with keywords or phrases [28]. Others might also try illustrating students' hobbies in phases or words and connect them with probabilities [29]. Those researches mainly focus on representing the domain knowledge with keywords or phrases and representing them on a 2D knowledge graph. However, with the development of VR devices and the metaverse concept, we could have another approach that visualises the domain knowledge in 3D space and integrate the knowledge in a novel way.

3 Methodology

3.1 Connect the Metaverse Service and Application

We posit that the future landscape will not be dominated by a singular Metaverse but rather will consist of an array of metaverse-related applications and developments. These will likely be interconnected through concepts such as digital identity and digital ownership. Given these considerations, we have sought to distill the concept of the Metaverse for educational purposes into a more accessible three-layer structure for educator (see Fig. 2).

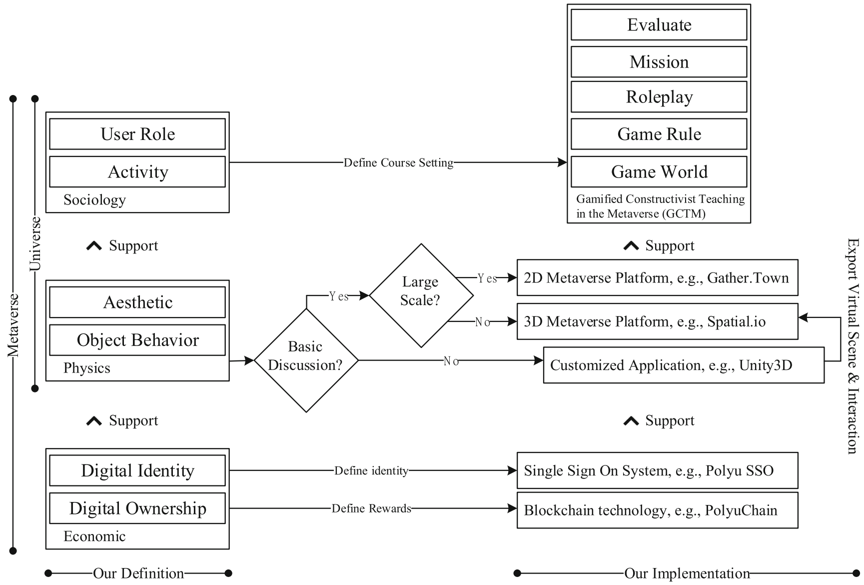


Fig. 2. Our Definition and implementation of Metaverse in Education

The uppermost layer in our conceptual framework for education within the Metaverse is the sociological layer, concerning the design of user roles and activities for students in the virtual world, essentially constituting the course setting. Upon entering the virtual world, students are represented through avatars, and thus, they anticipate adopting diverse roles to partake in various activities, akin to experiencing another reality. This layer emphasizes the importance of well-defined roles and structured activities, allowing students to engage meaningfully within the virtual space. We have articulated a specific framework to guide this complex design process, termed Gamified Constructivist Teaching in the Metaverse (GCTM), which will be elaborated upon in the subsequent section. By foregrounding the sociological aspects of interaction within the virtual realm, this layer facilitates an enhanced understanding of how students can immerse, engage, and learn through alternate personas and meticulously crafted activities, reflecting the multifaceted nature of human interaction and learning in virtual environments.

The intermediate layer of our conceptual framework pertains to the physical layer, i.e., virtual world, within the Metaverse, encompassing both the aesthetic and object behavior in the virtual realm. The aesthetic refers to a philosophical understanding, reflecting the nature and style of the art employed within the virtual world. Contrary to some perceptions, the Metaverse does not necessarily require the use of mixed reality technologies [16], and the virtual experience can be realized through various mediums, such as VR, 3D, 2D, or even text-based interfaces [30]. Examples of text-based virtual worlds include the renowned board game, Dungeons & Dragons [31], and platforms like

Whatsapp, Facebook, and Instagram, which Meta regards as integral parts of their Metaverse. The choice between VR, 3D, 2D, text-based, or a combination of these mediums should be driven by considerations of cognitive expenditure and the duration of activity. From our observations, VR or 3D is suggested for small group discussions or tutorials where students can focus more completely on full-bodied interactions. Conversely, for larger classes, a 2D environment with strategic camera settings is recommended to avoid potential cognitive overload, as recognizing numerous 3D avatars simultaneously can be challenging. Text-based interfaces can function as integral tools within the virtual world, serving as forums or message boards. Discord, as a popular platform for information exchange, exemplifies this utility. Furthermore, the physical layer necessitates a precise orchestration of object behavior, establishing connections between virtual objects, their attributes, and functionalities to guarantee the fulfillment of their predefined roles. If traditional virtual discussion tools, such as camera or screen sharing, fall short of specific requirements, a standard metaverse platform may prove inadequate. Under such circumstances, the development of a customized application becomes essential to craft a more engaging and facilitative discussion environment. Once tailored to the specific needs, the virtual scene can then be integrated into the broader metaverse platform, thereby enriching the overall learning experience.

The first and second layers together delineate the virtual world's configuration, forming what we refer to as a "universe." If such a universe is crafted with educational intent, it becomes an "eduverse." As the applications and needs diversify, we foresee the creation of multiple universes, each tailored to specific purposes. For instance, an eduverse designed to simulate a hospital environment for healthcare education would incorporate unique functions relevant to that setting but not utilized in other eduverses. We term this diverse landscape a "multiverse." To bind these disparate eduverses into a cohesive Eduverse or Edu-Metaverse, the inclusion of a third layer is essential—the economic layer. This layer shapes the system of rewards and exchanges, allowing students to share value across different eduverses. Depending on factors such as security and usability, this economic layer can adopt centralized, decentralized, or hybrid approaches.

The economic layer consists of two essential elements warrant attention. The first one is digital identity. This constitutes the information used by the eduverse to recognize individual students. In our design, we utilize a single sign-on (SSO) system within our university, requiring students to log in with their specific student credentials. The flexibility of the system allows integration with various SSO options, such as Google, Facebook, or WeChat, across different eduverse platforms. There's also the option to permit anonymity, fostering more open peer-to-peer learning during discussions. The second one is digital ownership: Encouraging active student participation in virtual activities is vital. By employing gamification and Play2Earn principles, we generate virtual coins as rewards for students. We have developed specific apps like PolyU WellFit and PolyU GreenCoin to support holistic education. Recent advancements in blockchain technologies have been beneficial in this regard [32]. Our transaction across all apps is linked to PolyChain, a generic blockchain platform, ensuring seamless integration.

In summary, the Eduverse concept within our university encapsulates various virtual worlds and apps, interconnected through SSO and blockchain technology. This multi-faceted structure fosters a vibrant and dynamic learning ecosystem, leveraging the best of both virtual and real-world educational strategies.

3.2 Connect Students by Using Gamification and Constructive Teaching

The metaverse offers a novel learning environment, presenting opportunities to innovate and evolve pedagogical strategies. We contend that the application of the metaverse in education should extend beyond mere replication of traditional lecture halls or tutorial classes. Instead, new approaches that harness the unique capabilities of this virtual space should be explored. In this section, we will delineate the methodology for utilizing the structure of role-playing games (RPG) and the principles of constructivism to design an educational course setting within the metaverse.

Changes in the learning behaviors of our students warrant attention, as these shifts are not isolated from broader cultural phenomena. Some scholars have attributed the resurgence of the metaverse concept among students to the success of films like “Ready Player One” and “Free Guy” [33]. This connection between popular culture and learning suggests that immersive experiences in the metaverse can indeed act as motivational catalysts. We concur with this perspective, recognizing the potential for the metaverse to enrich the educational experience by engaging students in ways that resonate with contemporary cultural trends.

In the context of this project, we seek to introduce a novel pedagogical framework aimed at fostering student engagement and effective learning, namely, Gamified Constructivist Teaching in the Metaverse (GCTM). As the terminology indicates, GCTM is predicated on the integration of two well-established learning theories: gamification and constructivism (see Fig. 2). The main idea of GCTM is to create a new learning environment to support new learning activities and course design.

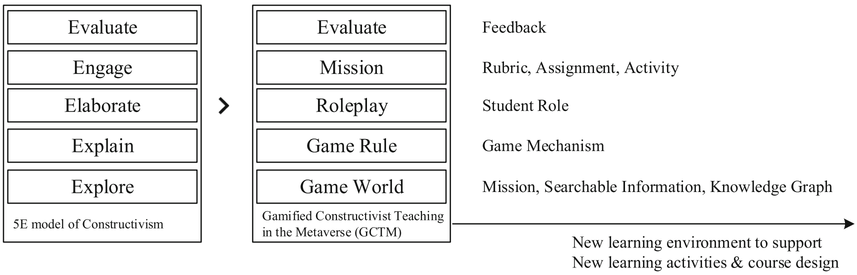


Fig. 3. Gamified Constructivist Teaching in the Metaverse (GCTM) framework

In the Game World Design, which aligns with the explore phase of the 5E model, the traditional systematic lecture approach is replaced with a more engaging strategy. Instead of delivering long talks on specific subjects, educators transform their lecture materials into three distinct components: 1) A well-defined Mission or objective related to the course. 2) Searchable information that students can access and explore; 3) A knowledge graph illustrating the interconnections between various materials; and The details of this setting will be covered in the next session. This innovative approach provides an interactive virtual environment and enables students to take on the role of players, embarking on new and exciting adventures within the Metaverse. By shifting from passive listening to active exploration, students are encouraged to engage with the material, fostering a deeper understanding and more interactive learning experience (Fig. 3).

Game Rule Design corresponds with the explain phase in the 5E model. Once the game world has been established, this stage requires lecturers to furnish an overview of the knowledge and theories to be learned, as well as delineate the connections among these learning contents. To augment the efficiency of this explanation, we advocate the incorporation of game mechanism design. Owing to the widespread success of mobile games, students are often already acquainted with various game mechanisms. Game designers leverage different game mechanisms to encourage players to explore various parts of the game, employing strategies like daily missions, urgent missions, level-up systems, first draws, and more. By performing similar tasks repeatedly, players learn how to navigate the game, developing new habits.

Roleplay Design aligns with the elaborate phase of the 5E model. Once various game mechanisms have been established to systematically convey knowledge, the focus moves beyond crafting open-ended or reflective questions. In this stage, we create specific roles for students within the Metaverse. For instance, students might take on the role of a STEM teacher and design a STEM workshop for primary school students or a game designer in a game company. It aims to transform students who may be passive or struggle with low motivation into engaged and active learners. By immersing them in a simulated environment where they take on professional or creative roles, we encourage them to internalize and apply their knowledge, making the learning experience more tangible and stimulating.

Mission Design corresponds to the engage phase in the 5E model. Educators at this level must create the content for tutorial exercises, assignments, and the final project. Since GCTM utilizes a game system approach, a well-defined rubric must be crafted and presented to the students. This assessment tool should articulate achievement criteria across all components, providing clarity on what is expected of the students. By laying out these expectations, the system helps to identify any knowledge gaps and ensures that students are aware of the learning objectives. The mission design thereby serves as a roadmap, guiding students through their educational journey and fostering a more interactive and engaging learning experience within the Metaverse environment.

Evaluate Design aligns with the evaluate phase in the 5E model. Within this stage, formal assessments are administered to the students using predefined rubrics, while informal assessments may occur during observations of students' discussions and interactions. This design goes beyond merely assessing academic results. It also takes into consideration the learner's experience within the GCTM framework. By incorporating both formal and informal evaluations, educators can gain a comprehensive understanding of not only the students' grasp of the material but also their engagement and satisfaction within the educational environment. This holistic approach helps in creating a more effective and responsive learning experience tailored to the unique demands and opportunities of the virtual world.

3.3 Connection with the Domain Knowledge

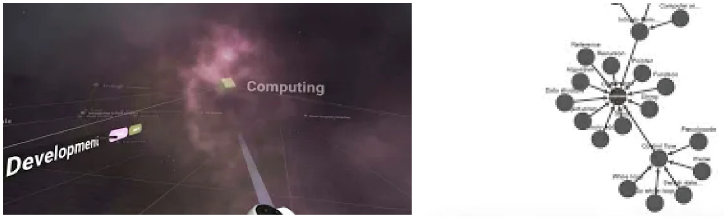
The essence of the game world design component, as well as the GCTM framework, lies in deconstructing domain knowledge into specific missions, searchable information, and a cohesive knowledge graph. This approach enables a more interactive and engaging learning experience, transforming traditional educational content into an adventure within the Metaverse.

Mission: The starting point for lecturers is to define a clear and engaging mission for the students. Examples might include acting as a STEM teacher to develop machine learning courses for primary students or serving as a legislator to evaluate public policy. This mission serves as the goal, with all assignments and activities aligned to support its completion.

Searchable Materials: Instead of traditional slides and lecture recordings, materials must be transformed into bite-sized, searchable resources. This approach enables students to actively explore and discover knowledge within the game world. If videos are the primary learning resources, our research indicates that long videos are not as effective for learning. Shorter video clips, averaging around 8 min and 43 s, have proven more effective in our studies. Technologies like Azure Cognitive Service or Panopto, utilizing AI models for face recognition, translation, computer vision, and speech, can automatically tag and caption videos, enhancing the search experience across a library. Along with this, lecture slides and reading materials should be converted into searchable PDFs. In alignment with the Metaverse concept, materials should consider digital ownership, possibly using blockchain to publicly register content creation.

Systematic Graph: When dealing with vast amounts of searchable knowledge, it's vital to provide an overview that illustrates how different pieces of information are organized and interconnected. This can be likened to skill trees in RPG games, helping students understand their learning journey. While a hierarchical or tree structure is common, some connections between knowledge nodes may create cycles. In our implementation, we use a knowledge graph, a graph-structured presentation of connections between knowledge elements (See Fig. 4). The left-hand side presents a 3D and VR version of our work, showcasing knowledge nodes with slide previews. The right-hand side displays a 2D and web version, providing an easy-to-use interface for students to grasp an overview of the knowledge structure.

In summary, this design fosters an engaging and interactive learning environment by transforming traditional educational content into a Metaverse adventure. Through the careful crafting of missions, searchable materials, and a systematic knowledge graph, educators can encourage active exploration and learning among their students.



(a) VR Knowledge Graph (Link) (b) 2D Knowledge Graph (Link)

Fig. 4. Knowledge graph in GCTM framework

4 Evaluation

The GCTM (Gamified Constructivist Teaching in the Metaverse) framework was implemented in one subject across two engineering classes, with 62 students in one class and over 200 in the other, utilizing the Gather.Town platform. The evaluation of this project was conducted using a combination of tools: a questionnaire designed around the 5I model, the university's standard student feedback questionnaire (SFQ), and a review of the students' academic results at the conclusion of the semester.

The aim of this evaluation was to uncover the relationship between the students' backgrounds and their satisfaction with the GCTM approach. The questions were constructed using a 5-point Likert scale, ranging from 1 for "Strongly Disagree" to 5 for "Strongly Agree." This format facilitated an in-depth understanding of the students' experiences and allowed for a detailed assessment of the GCTM's efficacy in the context of their learning as shown in Table 3.

Our data observation reveals a positive reception of the GCTM setting, with almost all items receiving a rating over four in the larger class. When comparing the satisfaction levels between the virtual world setting and traditional platforms like ZOOM or MS Teams, we found that the virtual world fosters a stronger sense of belonging among students. The interaction rating, which measures both student-to-student and student-to-lecturer interactions, is relatively high. This suggests that the GCTM design enhances opportunities for students to engage with both their lecturers and peers compared to traditional methods. Our observations, as well as student feedback, indicate that when given ample preview and explanation about the tasks and roleplay, students are more willing to exchange ideas and actively participate in discussions. Rather than simply typing answers in the chat, they are more inclined to turn on their cameras and verbally engage, adding a more dynamic and interactive dimension to the learning experience. We have also garnered positive feedback on GCTM, as outlined below. The comments highlight that student enjoyed the enhanced interaction with the lecturer and appreciated this innovative approach:

Comments on Metaverse Platform

- Interesting and effective teaching mode especially using gather town, which is an interesting thing to me
- I like the group assignment that work together in the metaverse learning environment.

Table 3. Student Satisfaction

Item	COMP N = 209	EIE N = 62
Satisfaction (Content)		
Slides	4.00	3.69
Video	4.12	4.03
Satisfaction (Teaching Activities)		
Preview Session	3.86	3.76
Q&A Session	3.84	3.73
Satisfaction (Learning Activities)		
Overall	4.10	4.18
Engagement	3.87	4.00
Reflection	3.82	3.84
Understand	3.91	3.77
Satisfaction (Virtual environment)		
Easy to use	4.32	4.15
Stable	4.14	4.05
More comfortable environment	4.11	3.95
Better sense of belonging	4.11	3.85
Better team building	4.08	3.98
Improve Student-student interaction	4.11	3.95
Improve Student-lecturer interaction	4.06	3.95

COMP = Year 3 students in Department of Computing.
EIE = Year 4 students in Department of Electronic and Information Engineering.

- The topics are interesting and allow me to explore the other side of computer. The idea of collaboration through metaverse is really good and helpful.

  Comments on GCTM

- Use independent watching videos to learn, and the teaching method of answering questions in class is very efficient and high-quality
- Watch video in YouTube and consult in class is good teaching method for me, helping me to have a good time management.
- Lecturer already gives me a lot of help on this course, give a very good explanation on the topic by recording video and lectures notes. I am appreciating it.
- Flipped classroom, so that students can use the time on lecture to communicate with teacher.

- He spends so many times to teach us and answer our question one by one.
- The Q&A time during class. I always learn more through asking questions.
- The flipped learning teaching mode.

5 Conclusion

In conclusion, this paper has presented the Gamified Constructivist Teaching in the Metaverse (GCTM) framework, a novel approach to educational engagement in the computer science field. Through the integration of game world design, game rule design, roleplay design, mission design, and evaluate design, GCTM has been shown to enhance student-student interaction, student-lecturer interaction and increase satisfaction levels in the learning environment.

The implementation of GCTM in two engineering classes, utilizing the metaverse platform, revealed promising results. The systematic arrangement of missions, searchable materials, and knowledge graphs created an engaging and immersive educational setting, fostering a stronger sense of belonging and interaction among students.

Furthermore, the positive feedback received from students affirms the success of this approach in enhancing the educational experience. The high ratings across various components of the program, along with students' verbal appreciations, showcase the potential of GCTM in transforming conventional education methodologies.

However, it is essential to recognize that this study represents an initial exploration of the concept. Future research could focus on optimizing various elements of GCTM, implementing it across diverse educational fields, and conducting more extensive evaluations.

Overall, GCTM represents a significant step forward in the integration of gamification and constructivist principles within the virtual world of education. Its success in the observed classes underscores its potential as a versatile and effective tool for modern educators, potentially paving the way for a more engaging, interactive, and learner-centered educational landscape.

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