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Research Article

Level-Up Learning with CIGLE Framework: Enhancing Learning Through Interactive, Game-Based Collaboration for Effective Problem Solving

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Abstract: Several institutions promote student collaboration, which are beyond transmission of academic knowledge to the cultivation of critical thinking and problem-solving skills. However, the collaboration process was disrupted in higher education by the COVID-19 pandemic, which hindered students effectiveness and contributed to a passive learning style due to the traditional teaching method. This passive and one-size-fits-all teaching method, limited student engagement, decreased motivation, collaboration, problem-solving skills and prevented diverse learning styles. The shift to technology-oriented learning environments including Digital games, Artificial Intelligence (AI), Augmented Reality (AR)/Virtual Reality (VR) tools necessitated innovative solutions to maintain and enhance educational quality. Therefore, this research aimed to address the challenges by introducing the Collaborative and Interactive Game-Based Learning Environment (CIGLE) to create a dynamic and interactive educational experience. This is mixed method research with data collected to determine students responses on motivation, engagement, collaborative problem-solving, and communication. Quantitative data were collected through an online 5-point Likert scale survey, with pre- and post-tests. Qualitative data were gathered through open-ended questions to gain deeper insights into students perspectives on the community-integrated game-based learning environment. The result showed that students engagement, collaboration, critical thinking, and problem-solving abilities significantly improved through the incorporation of these innovative pedagogical approaches and technological tools. In conclusion, implementing the CIGLE framework in classrooms effectively fostered energetic Communities of Practice (CoP) and remarkably promoted students learning experience.

Keywords: AI in education; Collaborative learning; Communities of practice; Game-based learning; Learning ecosystem

1. Introduction

The educational environment is influenced by the society, technology and economy, depicting the significance for institutions to remain adaptable and responsive to the diverse learner needs. Based on this, the continually adaption to instructional methods, curriculum design, technology,

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and support services, ensured that education remained relevant, effective, and inclusive in addressing the challenges and opportunities offered by modern higher learning (Akour & Alenezi, 2022; Godin, 2021).

In view of this, traditional learning relied on physical presence in classrooms with instructors, assessed through tests and texts. The process also included face-to-face interactions, consistently proven effective for subjects that benefit from direct instructor engagement and hands-on activities. These methods are well-suited for disciplines requiring practical experience or immediate feedback, such as laboratory work or technical skills. However, the COVID-19 pandemic impacted the conventional teaching methods, resulting in improved digital transformation, as well as significant challenges (Mutya and Masuhay, 2023; Collazos et al., 2021; Asvial, 2021). Furthermore, the availability of several technologies, including games, Artificial Intelligence (AI) tools as a learning assistant, and Augmented Reality/Virtual Reality (AR/VR), does not conform with pedagogical objectives or the specific need of student learning outcomes (Flórez Marulanda, 2023; Neo et al., 2022). The rapid advancement of information technology had profoundly influenced various aspects of life, particularly the educational sector. As a result, the proliferation of digital tools and platforms, including games, AI, and AR/VR, had transformed how knowledge was accessed and delivered. Prior research reported that digital games led to increased engagement, motivating students during the learning process (Muñoz, 2023). Additionally, AI tools such as machine and natural language processing, enabled personalized learning experiences, and educational content to adapt to individual student needs and preferences (Kabudi, 2021). The integration in learning environments prompted engagement, fostering critical thinking, and exploration of concepts interactively. Understanding these developments was crucial for discussing the role of technologies in modern education. This inconsistency hindered effective implementation, limiting the potential for collaboration, problem-solving, and critical thinking. Consequently, issues such as unequal access to resources and varied levels of digital literacy further complicated the integration process, especially in fields that had relied on direct, hands-on instruction (Mutya and Masuhay, 2023).

Post-pandemic, blended and face-to-face teaching environments encountered similar challenges (Izzati et al., 2024; Intra et al., 2023; Tai et al., 2022; Ashour et al., 2021). These currently focused on formulating flexible and engaging learning environments designed to suit the tech-savvy Gen Z (Tai et al., 2022; Kerimbayev et al., 2023).

Based on this, higher education faced significant challenges in offering flexible study options and fostering active learning, asides from the digital revolution. According to Børte et al., (2023), firm support structures are essential for the successful implementation of active learning, although technological and physical resources do not conform with the teaching needs. Empowerment through active learning (Li et al., 2023) and collaborative efforts (Nurdiana et al., 2023) allowed students to become responsible for the process, including engaging in real-time problem-solving (Xu et al., 2023). This led to improved experiences, team dynamics, and intrinsic motivation to achieve set objectives (Ramirez Villegas et al., 2023; Galvis & Carvajal, 2022).

Prior research stated that student cognitive abilities, decision-making skills, leadership qualities, and time management were improved through the integration of social engagement, peer collaboration, technological tools such as digital games and AI, as well as community discourse (Thornhill-Miller et al., 2023; Galvis & Carvajal, 2022; Teoh, 2022). While social media often supported community-driven learning, the structure should systematically address educational needs, equipping students for future challenges.

Fraser (2023) and Al-Said (2023), stated that current educational environments struggle to engage and inspire students, which led to decreased motivation, limited interaction, and inadequate collaboration. These challenges were moderated by integrating educational games into contemporary teaching and learning environments, supported by AI, to enhance student engagement and motivation. The following sections explored the application and effectiveness of CoP and GBL within educational contexts, focusing mainly on AI-supported gaming to enhance critical thinking and problem-solving skills, outlining the potential to foster and improve learning outcomes.

1.1. Communities of Practice (CoP)

Wenger and Wenger (2020), stated that CoP refers to a group of individuals who regularly engage in enhancing knowledge and skills while sharing a common concern, set of problems, or enthusiasm for a subject. Members actively partake in interactive discussions to advance expertise and gain valuable experience in respective fields. CoPs serve as forums where individuals with shared interests convene to deepen understanding and proficiency in respective domains (Thomson et al., 2021). The members also support the development of each other, through the exchange of knowledge within this collaborative environment.

Mao et al. (2021), stated that the research was inspired by a collaborative GBL environment centred on problem-solving. The environment comprised three main components, namely domain, community, and practice, which created a classroom avenue where students interacted and collaborated during assignments (Wenger and Wenger, 2020). The research on CoPs stated that the method enhanced knowledge growth and exchange, thereby enhancing the effectiveness of practices conducted within and between organisations (Bastiaens and Heymann, 2023; Scott et al., 2023).

CoPs are beneficial organisational structures, which enables the adaptation of teaching and learning environments. This method had been proven to facilitate participant dialogue, learning, and knowledge exchange, contributing to objectives such as boundary transcending, trust establishment, consistent engagement, and mutual learning. The research also stated that CoPs can be effectively adapted to in educational environments, enhancing collaborative knowledge development in task-focused contexts as interactive learning tools are continuously improved (Shepherd and Bolliger, 2023). Therefore, structuring it for higher education to maximize the benefits is important (Bootz & Lievre, 2023; Parrish et al., 2021).

1.2. Game-Based Learning (GBL) Approach

There had been significant scholarly attention toward GBL in recent years, particularly within higher education settings. An increasing number of research had explored the advantages of integrating games into educational curricula, indicating the positive impact on student motivation, classroom engagement, and overall learning outcomes. Preliminary research had reported that GBL fostered active participation, increasing student critical thinking skills, problem-solving abilities, and content retention. Additionally, Udeozor et al. (2023) stated that educational games contributed to an enjoyable learning experience, prompting a sense of ease and confidence, as well as enabling students to address various challenges with patience and focused attention.

Zahra et al. (2022) explored the varied nature of GBL benefits and reported that effectiveness depended on contextual factors and implemented strategies. According to Nadeem et al. (2023), this method had significantly increased intrinsic motivation and student engagement. Gee (2005), stated that these ideas can be categorised into three elements namely a) empowered learners allowing the freedom to actively participate in the educational experience, fostering heightened engagement and learning ownership, b) enhanced problem-solving well-designed challenges and exercises within GBL environments leading to effectively improved problem-solving and critical thinking skills, and c) improved understanding of GBL, inspired the development of critical thinking skills, resulting in informed decision-making when faced with various scenarios.

1.2.1. Role Playing and Competition in GBL

Learners endeavour to outperform each other in competitive GBL environments in order to win the game. Several research had reported the positive influence on learning performance, engagement, and motivation (Barz et al., 2023; Muñoz et al., 2023; Nadeem et al., 2023), leading to the persistence in solving problems to achieve set objectives. Zou et al. (2021), conducted similar research and reported that students who participated in competitive modes performed better in post-tests.

Games are currently designed for entertainment and informal learning purposes, outlining the significance to develop information literacy systems within educational contexts (Harvey, 2024). The students monitor respective scores and rankings using a leaderboard throughout the learning process, reviewing performance later for future improvement. According to Chen and Wu (2021), games with role-playing features stimulate critical thinking, enabling deep engagement in the learning environment. Moreover, the immersive experience of games enhanced student motivation toward the learning process (López-Fernández et al., 2023).

1.2.2. AI in Game Assistance

AI-driven game assistance has transformed student engagement with educational content, fostering a dynamic and responsive learning experience (Rane et al., 2023). GBL environments used AI to deliver personalized guidance and support, significantly improving engagement and learning outcomes (Nguyen et al., 2024; Neo et al., 2022).

AI algorithms consistently monitored students interactions, behaviours, and performance in these games, enabling real-time feedback, support, and personalised hints based on individual needs (Hooda et al., 2022; Young et al., 2012). This method empowered students to navigate challenges, overcome obstacles, and progress independently, thereby ensuring a more effective and customised learning journey (Dyulicheva and Glazieva, 2022).

Several research had validated the efficacy of AI in GBL for example, Zhai et al. (2021) investigated the role in adaptive educational games, demonstrating the ability to enhance student motivation and learning efficiency significantly. Additionally, Kabudi et al. (2021) explored how intelligent tutoring systems, a type of AI assistance, deliver personalised educational experiences that enhance performance and knowledge retention.

AI-driven analytics can discern student learning patterns, providing educators with insights into areas where additional support or intervention may be needed. This data-driven method facilitated ongoing improvements to educational games, making it more effective and engaging for learners (Dyulicheva and Glazieva, 2022).

Based on this perspective, the integration of AI into GBL environments represented a substantial advancement in educational technology, equipping students with the tools and support necessary to thrive in an interactive digital landscape (Sun et al., 2023; Flórez Marulanda et al., 2023; Berawi, 2020).

In view of this, Communities of Practice (CoP) tend to promote collaboration in higher education, including addressing related challenges. The strategies adopted were underutilised, leading to the need for further exploration from pedagogical perspectives (Thomson et al., 2021). Contemporary learning environments encountered significant obstacles, resulting in reduced motivation, limited interaction, and inadequate collaboration (Marsevani, 2022). Although, Games and AI tools offered significant advantages when applied in educational settings (Harry et al., 2023; Sun et al., 2023), several challenges must be considered during the implementation process.

This research explored student perceptions of integrating CoP and Game-Based Learning (GBL), supported by AI, to enhance engagement, motivation, collaborative problem-solving, critical thinking, and individual performance in higher education. It also examined the role of AI in enhancing gaming experiences to improve learning outcomes and performances. Subsequent sections provided detailed analyses of these approaches, supported by diverse evidences and case studies.

The research is structured into Section 1 focused on a comprehensive Introduction of CoP and GBL concepts, including competition in GBL and AI-driven game assistance. Furthermore, section 2 is a detailed description of the methodology, as well as the learning environment design and data collection methods. Section 3 presented the results and discussion, including student profiles, pre and post-test performance analyses, detailed survey responses with Exploratory Factor Analysis (EFA), and Cronbach Alpha test to determine reliability. Finally, Section 4 is a summary of the findings and recommendations for future research.

2. Methodology

The section focused on the method and distinct step used in this research. The first step described the design of the gaming instrument, integrating educational pedagogy and a multiplayer model to enrich the learning experience. The second provided a detailed description of the implemented CoP and GBL theories in a classroom setting, alongside methods, procedures, and tools adopted for data collection and analysis of participant responses. These steps led to a comprehensive understanding of the research design and method.

2.1. Design of the Collaborative Game

The educational game EduBattle was innovatively designed by faculty members at Multimedia University to enrich learning experiences. The game fostered a collaborative environment aimed at community building and knowledge acquisition. EduBattle also helped in improving problem-solving and critical-thinking skills through two main components, namely knowledge assessment and practical scenario implementation. The students were required to create individual accounts with customisable avatars, in order to engage in team collaboration. With guidance from an AI assistant, the students navigated through certain challenges, namely responded to queries, and confronted simulated alien encounters. Furthermore, EduBattle promoted a deeper understanding and retention of course content by blending role-playing with gameplay mechanics. This proved the potential of gamification to offer a compelling and interactive educational experience.

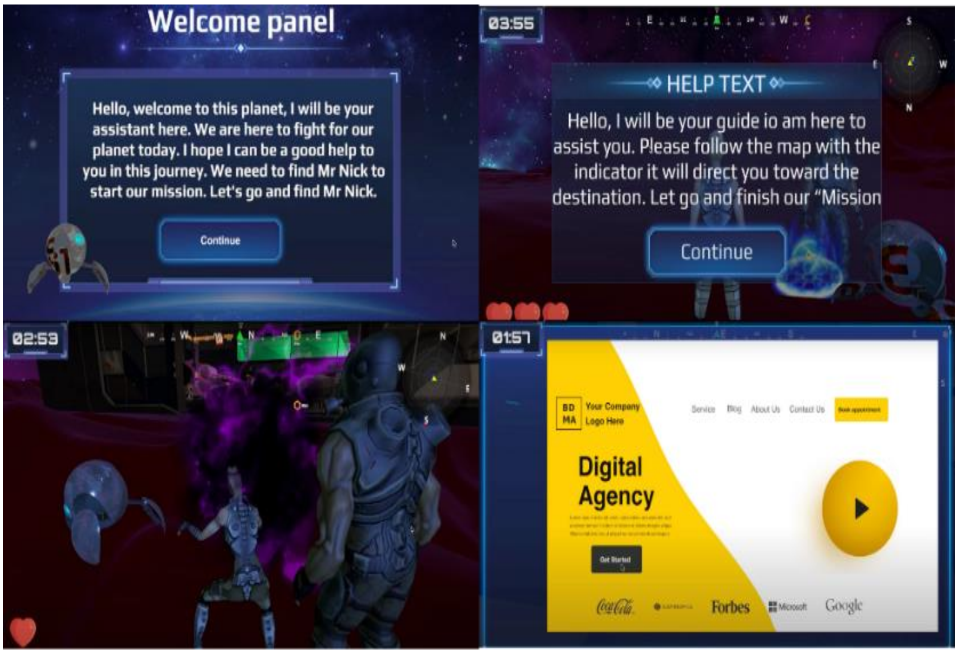

Figure 1 Capturing Key Elements of the Collaborative Educational Gaming Experience

As a GBL tool EduBattle incorporated the content of Mobile Application Design and Development course, and with the help of teachers educational objectives were tested, in line with motivating critical thinking and collaborative problem-solving. This game inspired the use of acquired knowledge practically by grouping the students during certain tasks and challenges mimicing real-world situations in respect to the course material. Moreover, game mechanics was incorporated as a measurement tool, enabling real-time monitoring and evaluation of collaborative processes, as well as providing measurable insights into team dynamics and individual contributions.

Students were organized into competitive teams, because the game mechanics were designed to promote meaningful intra-group collaboration. Each team strategized collectively during the quest time, communicating with each other through shared knowledge, making decisions based on individual strengths. This ensured that the group success was dependent on effective collaboration. However, to further promote engagement, gamification elements such as scoring, rewards, and level progression, were incorporated to motivate students, monitoring and measuring participation and performance. The gamification metrics served as data points used to assess both individual and group progresses.

A feedback mechanism served as an essential element for assessing collaborative learning among students. The designed learning and gaming ecosystem provided immediate feedback on collaborative effectiveness, by continuously monitoring performances, including inter and intra-group interactions. This real-time mechanics helped to assess the overall group dynamics and individual performances within the team, including learning outcomes. In addition, EduBattle was developed around the selected course material that comprised assessments and practical scenarios designed to suit the subject matter and student needs. An integrated AI assistant played a significant role in this framework by motivating students, resulting in effective time management, alerting imminent threats within the gameplay and prompting the completion of task by providing feedback.

The students accessed the game from a downloadable link through Google Drive in the physical classroom. On installation, learners engaged with the game by selecting avatars and forming teams, where each group member faced own monitor screen. This setup facilitated team communication and collaboration during gameplay. The learning experience was structured to allow students engage with the educational game, followed by practical activities conducted in the physical classroom. Instructors played an active role in this process, serving as facilitators and material providers, guiding students through project assignments, on-site game mechanics, and group activities that reinforced both theoretical concepts and practical knowledge of the subject.

2.2. Implementation of Theories in Classroom

The Mobile Application Design and Development course at the Faculty of Creative Multimedia was redesigned to incorporate GBL elements alongside CoP method. This was aimed to cultivate a collaborative environment that improved problem-solving skills and real-time performance. Additionally, the course was delivered in-person, focusing on direct communication between both parties.

In order to implement Wenger CoP principles, the activities were re-designed and divided into two parts as assignments, in class group tasks and individual projects to stimulate active student participation, motivate knowledge-sharing, fostering collaborative problem-solving. The main research objective was to promote motivation and engagement through interactive gaming techniques, using the competitive aspects inherent in games. The collaborative activities were designed in association with the subject method expert to promote active engagement and interdependence among group members. Each activity was structured to ensure students worked together, improving individual knowledge, including relying on the contributions of one another to complete assigned task. This was realized by assigning roles within groups, ensuring each participant had specific responsibilities. Moreover, the roles prompted accountability and ensured balanced participation, preventing any member from dominating or disengaging.

Collaboration was facilitated by dividing the tasks into multiple brief activities and assignments, requiring different perspectives and skills. As a result, the students had to communicate, negotiate, and synthesis individual contributions to complete the tasks and assignments, thereby achieving collective success. Activities were scaffolded to build complexity over time, starting with simpler tasks to develop group dynamics and moving toward more complex problem-solving assignments that required deeper collaboration and critical thinking.

These activities were supported by prompts and guiding questions in addition to structured roles that motivated open dialogue, critical discussion, and reflection. The prompts guided students toward higher-order thinking and deeper analysis, while peer assessments were incorporated to foster self-reflection in group dynamics and individual contributions.

The method integrated CoP principles to establish a supportive learning environment. During group activities and final individual projects, students collaborated, shared expertise, and addressed real-world design challenges to foster a sense of ownership and community within the learning environment. Tables 1 and 2 show how course components in line with Wenger CoP model adopted game-based learning strategies. This research assessed student perceptions and responses to a collaborative, game-based learning environment aimed at nurturing communities in the classroom. Subsequent sections provided a detailed exploration of the implemented game-based collaborative community practices in the classroom.

2.2.1. Game-Based Learning (GBL) Application

The research integrated the principles of CoP and GBL in the classroom environment to promote community-driven learning and enhance collaboration, communication, problem-solving, and decision-making skills, prompting active participation in the learning process. The method used the strengths of both frameworks, to create an active collaborative learning environment enriched with game elements, thereby enhancing engagement and interaction. Prior to the implementation process, the classroom was subjected to restructuring and redesign to conform with the subject matter and transferable skills. Subsequently, the conceptual framework was introduced into the classroom setting. Table 1 shows the application of these principles in the classroom and game to optimise student learning and participation.

Table 1 GBL Class Application.

GBL	Game Application	Class Application
Learner Empowerment	1. Students can select own character/avatar 2. Students select members of the team prior to playing the game	1. Students were assigned roles in the group according to respective expertise 2. Consistent improvement were recorded throughout the trimester 3. Various activities were designed for knowledge sharing and development.
Problem-Solving	1. A well-designed problem was introduced in the game, with increasingly difficulty levels and multiple challenges. 2. Time constraints incorporated to increase challenge level. 3. A systematic cycle was designed with multiple stages in the game. 4. An AI bot was integrated inside the game to provide verbal instruction when needed.	Assignments and problem-solving activities were strategically planned or designed for each week to support student knowledge construction and problem-solving skills.
Understanding	1. Each level was provided with an environment where students could interact with game objects to strategize next move. Also, fostered problem-solving, critical thinking and decision-making skills simultaneously. 2. An action storyline was integrated for players to interact.	1. Students were assigned individual project but motivated to collaborate with peers to solve problems and develop creative solution or idea. 2. Students engaged deeply with the multiplayer game to construct knowledge and exhibit comprehension of the course material. 3. Final project outcomes were presented to the lecturer to show understanding of the course content.

Throughout the trimester, students had consistent opportunities to improve and monitor own progress, ensuring continuous skill and knowledge development. Various group activities were strategically designed to foster active participation and cultivate a collaborative classroom atmosphere. Each group member was assigned a role based on individual expertise to facilitate knowledge sharing and skill enhancement. Additionally, students engaged in weekly problem-solving activities aimed at promoting knowledge construction. Individual projects which focused on solving real-world problems and devising creative solutions were assumed.

The educational game design followed Gee (2005) related learning principles, where students selected characters or avatars, formed teams, and engaged in competitive arenas. The game featured progressively challenging problems and multiple obstacles that needed to be overcome, enhancing the difficulty level. In order to intensify the challenge, time constraints were introduced, following a structured cycle with multiple stages. An AI bot provided verbal instructions as required, fostering interactive gameplay and motivating students to re-strategize.

An action-packed storyline was integrated into the game, allowing players to get immerse in the narrative, further enhancing engagement. This general approach aimed to develop student problem-solving, critical thinking, and decision-making abilities within an engaging and immersive educational context.

2.2.2. Community of Practices (CoP) Application

Wenger and Wenger (2020), defined CoP as collective groups of individuals bound by common interest or profession, engaging in collective learning through regular interaction. This method was characterised by three main elements, namely a shared practice that included the acquisition of knowledge and skills, group members who formed connections, and a particular area of interest. The present research used the potential features to design a pedagogically supported digital game, where CoP methods were integrated to foster student collaboration, thereby enhancing learning experience. The students were organized into teams, depicting a class-room setting where learners were intrinsically motivated to communicate, share knowledge, and support each other in problem-solving tasks. This class structure promoted individual accountability, outlining the importance of diverse perspectives, enriching the collaborative process (Bootz & Lievre, 2023; Bastiaens and Heymann, 2023).

The CoP framework facilitated the sharing of practices and strategies, allowing students to learn from experiences. The game prompted active participation in discussions and collaborative activities, reinforcing the collective understanding of course material. Moreover, the role of instructors as facilitators within the community further enhanced the learning environment, as students guided during interactions, helped in connecting theoretical concepts to practical applications. The research outlined the significance of social learning and community engagement in educational settings, by implementing CoP. This engaging method, motivated students intrinsically, as well as helped in the acquisition of collaborative problem-solving abilities and high-order thinking required for success in the classroom and industry. Table 2 shows how the collaborative learning activities based on real-world scenarios and problems were carefully designed within the learning environment to enable students develop knowledge and improve respective skills.

After the integration of game-based principles and fostering community building among learners, lecturers, and industry experts, each student was assigned well-structured case studies and projects designed to suit individual interests and expertise. These assignments aimed to assess respective understanding of the course content delivered.

The integration of real-world scenarios, collaborative team activities, detailed case studies, personalised individual projects, and an interactive gaming component created a comprehensive, community-centred, and immersive learning experience. This method significantly enhanced students understanding, problem-solving abilities, and collaborative skills, effectively leading to preparations on how to address real-world challenges in the respective fields.

Table 2 CoP Class Application.

CoP	Class Application
Domain	In class: Real-world scenarios based on collaborative learning activities were designed in alliance with the subject method expert and requirement. Additionally, a properly designed case study was given to individual students to test the understanding of the knowledge that the lecturer impacted in the class. Besides each were assigned individual project based on interest and expertise. i) Real-World Scenarios and Team Activities Real world Scenarios Team activities Case studies Individual Projects
Community	In class Students formed a team, selecting a topic for the team activities and individual projects. Furthermore, knowledge and ideas were shared during tasks to complete assigned activities, working towards the same objectives. i) Team Formation and Topic Selection a) Team Activities b) List of Topics c) Individual Projects ii) Knowledge Sharing and Collaboration Shared Knowledge Collaborative Goals
Practice	In class the students were given multiple assignments, including group activities to help prepare for the final projects. Multiple tools were recommended by subject method expert for the completion of tasks and provision of expert feedbacks. i) Assignments and Group Activities ii) Use of Tools iii) Expert Feedback

2.3. Method of Data Collection

The subsection provided an overview of the data collection methods used during the analysis, describing the procedures, tools, participant response, and data techniques. The objective focused on a comprehensive understanding of how the data was systematically gathered and analysed to ensure the reliability and validity of the findings.

2.3.1. Procedures and Tools

The research adopted mixed-methods, using convenience sampling to recruit 169 participants, mostly second and third year diploma students for pre, and post-tests, including a game session, and survey. The participants were required to sign agreement forms confirming voluntary participation, ensuring grades or marks awarded to assignment remained unaffected. The sample comprised 169 participants from multiple batches under the same subject and lecturer, with each consisting of 57 to 73 individuals.

After the collection of signed consent forms, a 10 to 15-minute presentation was conducted. This included a brief demonstration of the game and an explanation of the rules for participants who volunteered to participate. Furthermore, the purpose of the data collection process was clearly communicated to all participants during the session.

2.3.2. Participant Response Gathering

The participants completed a pre-test to assess the initial understanding of the subject matter. Subsequently, this included engaging in a gaming session designed to evaluate team dynamics, performance metrics, and enhancements in problem-solving, critical thinking, and collaborative skills. The interactive session typically lasted between 20 to 25 minutes.

Following the gaming session, students completed an online post-test, further evaluating knowledge acquisition and skills development. The participants also responded to open-ended questions and a survey designed to gather respective perspectives on the redesigned framework. The survey explored students experiences with the community-driven collaborative method facilitated by the customised educational game EduBattle throughout the learning process.

2.3.3. Data Analysis Techniques

The survey, informed by existing literature, aimed to explore perceptions of the proposed framework, focusing on four main aspects. These included enhancing problem-solving abilities, developing critical thinking skills, increasing motivation and participation, as well as fostering teamwork. Participants responded to the survey questions using a 5-point Likert scale, where five and one depicted Strongly Agree and Disagree, respectively. The scale provided a structured method to measure participant attitudes and experiences related to these critical dimensions of the educational intervention.

3. Results and Discussion

The section presented the demographics of the 169 participants who volunteered to participate in the research through a convenience sampling process, along with the results of the pre and post-tests. It also discussed the analysis of survey responses collected using a 5-point Likert scale questionnaire. Participant responses were analysed quantitatively using IBM SPSS software, including exploratory factor analysis (EFA), and reliability testing using Cronbach Alpha. Additionally, the section presented an outcome of student collaborative activities and individual projects, as well as the discussion of the outcome.

3.1. Pre and Post-Test of Students

The objective of the tests was to assess the student current level of subject comprehension. Before data collection, participants were briefed on the objectives of both the pre- and post-tests. Subsequently, the pre-test was completed, serving as an initial assessment tool for the research. The pre-test comprised 26 multiple-choice questions, including 20 general knowledge and six demographic questions covering consent, age, gender, nationality, race, and degree of study. Each participant required approximately 20 to 30 minutes to complete the test using Google Form in the classroom setting.

After data collection, IBM SPSS Statistics version 27 was used for the analysis. A paired sample t-test was conducted to assess significant changes in performances between the pre and post-tests. The statistical test aimed to determine if there were significant differences in the results before and after the intervention, with the findings from the analysis shown in Table 3.

Table 3 comprehensively analysed the statistics for the paired sample results of the pre- and post-tests. The post-test mean score is m=13.38, contrasting with m=8.09 for the pre-test. Statistical analysis in Table 3 outlined the significance of these results, with a 2-tailed test value of (P<0.001) depicting a remarkable difference between the two test sets. The T-test findings showed a significant improvement in student performance following participation in collaborative and competitive game-based activities. This outlined the effectiveness of collaborative game-based learning environments in enhancing comprehension and mastery of the material.

Table 3 Paired Sample T-test

		m= Mean	n= Numberof Participants	Std. Deviation		Std. Error Mean
Pair1	Post-Test Results	13.38	169	2.348		1.181
	Pre-Test Results	8.09	169	2.790		.215

Paired Sample T-test with Sig(2-tailed) Analysis

Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the difference		T	df	Sig (2-tailed)
			Lower	Upper			
5.296	3.48569	.268130	4.7665	5.8252	17.7511	169	

3.2. Student Survey Responses Overview

Following the completion of the pre and post-tests, including the educational gaming session, each participant was administered a survey questionnaire based on consent. This aimed to investigate perceptions of the Collaborative and Interactive Game-Based Learning Environment (CIGLE), the collaborative learning experience facilitated by the in-class activities and personalised EduBattle educational gaming session during the learning process. The survey questions were derived from established literature, and participant responses statistically evaluated using EFA and Cronbach Alpha, with detailed analysis discussed in the following section.

3.3. Exploratory Factor Analysis (EFA) of Student Response

EFA was conducted to analyse student responses, with the aim of reducing the dimensionality of the data and capturing as much variance as possible in a few components. This section presented the results of the statistical method used to ensure the accuracy of the survey items, including determining the cohesive structure of the factors (Goretzko et al., 2021; Watkins, 2018).

3.3.1. Factor Analysis

There are 169 survey responses analysed using SPSS, PCA was adopted for factor extraction, followed by Varimax rotation. This was widely used in factor extraction to identify linear components of variables, effectively explaining variance in the correlation matrix pattern and optimising dispersion of factor loadings. The Kaiser-Meyer-Olkin (KMO) sampling adequacy had a value of 0.916, signifying a high level of sampling adequacy. According to Kaiser (1974), KMO values greater than 0.8 were considered excellent, suggesting that the sample was highly suitable for factor analysis. These results showed that the correlations between items were sufficiently strong for conducting factor analysis.

3.4. Cronbach Alpha Test for Reliability

The reliability of 29-item survey scale was assessed using Cronbach Alpha. The results in Table 4, showed a high level of internal consistency among the items. The Cronbach Alpha value for the scale was 0.950, depicting excellent reliability. Additionally, when considering the standardised items, the reliability coefficient was slightly higher at 0.951. In the next subsection, Table 5 showed the mean, standard deviations, and aggregated mean for all five factors.

Table 4 Result of Cronbach Alpha for all 29 survey items.

Cronbach Alpha	Cronbach Alpha Based on Standardized Items	N of survey Items
Reliability is 0.950	0.951	29

3.4.1 Factor 1 Skill cultivation through collaboration

The students properly-received the community-integrated gaming learning environment, stating that it was enjoyable and beneficial for improving problem-solving skills. The results showed the strongly preference for group work as a method of acquiring new knowledge (Item 2: m=3.74). Majority of the students (Item 1: m=4.14) agreed that working in a group provided opportunities to explore and implement new ideas. Moreover, it was reported that group tasks helped in the better understanding of subjects (Item 3: m=3.81). This factor included items related to group work performance and task completion, reflecting the effectiveness and benefits of collaborative efforts.

3.4.2. Factor 2 Intrinsic Drive and Effective Engagement

Table 6 shows that participants positively interacted and engaged in the collaborative game-based learning environment. Moreover, smooth and engaging interactions were reported (Item 1: m=3.92), with participants enjoying respective group collaboration (Item 2: m=3.91). Students expressed happiness in sharing and implementing creative ideas in class (Item 3: m=3.91), with the feeling that ideas could be shared more effectively (Item 4: m=3.86). Moreover, successful task completion was depicted within the group (Item 5: m=3.85), outlining the importance of effective interaction and engagement in activating intrinsic motivation and practical collaborative learning experiences.

3.4.3. Factor 3 Development of Critical Thinking and Analytical Skills

Participants stated that the environment effectively enhanced respective abilities to apply and analyse concepts, as shown in Table 5. It was believed participants could implement what was learnt from class activities (Item 11: m=3.86). The students also realized the relevance between theory and practical implementation (Item 12: m=3.86) and felt capable of analysing different perspectives, to derive own inferences (Item 13: m=3.85). Furthermore, students reported the ability to examine how others gathered and interpreted information to assess the accuracy of inferences drawn (Item 14: m=3.84). The results showed that the ability to analyse essential elements of ideas, applying theories to practical or real-life problems effectively (Items 15 and 16: m=3.83, m=3.83). As a result, this factor outlined the development of student application of analytical skills through collaborative learning experiences.

3.4.4. Factor 4 Teamwork and Learning Dynamics

The students found group collaboration effective for overcoming individual challenges and improving various skills. Table 5 shows that the groups helped participants understand challenging concepts (Item 17: m=3.82), while learning to trust and empower group members (Item 18: m=3.81). The participants felt capable of making decisions more effectively (Item 19 m=3.81) and believed group tasks improved presentation skills (Item 20: m=3.80). Furthermore, students stated collaboration was more beneficial than working alone (Item 21: m=3.80). This factor outlined the value of collaborative learning in enhancing individual capabilities. Table 5 shows the detailed descriptive statistics analysis for Factor 4.

3.4.5. Factor 5 Personal Learning and Growth

The factor proved that students believed the knowledge acquired during class activities were valuable. Additionally, participants expressed confidence that knowledge gained from these activities tend to have practical benefits in the future (Item 22: mean = 3.74).

The participants were able to work more effectively (Item 23: m=3.74), including implementing what was learnt from group collaboration when carrying out project works (Item 24: m=3.69). This factor focused on the ability of students to apply group learning to individual tasks effectively.

The analysis of these five factors showed a comprehensive structure of group work experiences, focusing on performance, interpersonal relations, individual learning, collaborative benefits, satisfaction, and future application. Meanwhile, to enrich the results of the survey, students were urged to share respective perspectives on motivation, engagement, and teamwork. In addition, certain selected comments, were reported, for example a student expressed the zeal to excel academically, aiming for high GPA and personal growth. Others found collaborative problem-solving to be both enjoyable and effective. Furthermore, students reported that group projects facilitated better understanding and camaraderie among peers. The overwhelmingly positive responses reflected a genuine enthusiasm for incorporating gaming into future classroom experiences.

Table 5 Factor with mean, STD and Open-Ended Question Responses.

Items	Factors			
	Mean	STD	Agg	%
Factor 1				
1: I prefer to work in a group to learn new things.	4.14	.763	4.05	60.4
2: Working in a group provides the opportunity to explore and implement new ideas.	4.07	.799		81.7
3: Group members performed exceptionally in order to complete the task.	4.01	.886		69.8
4: The group task helped me to understand the subject better.	3.97	.702		63.3
Factor 2				
5: The interactions were smooth and engaging.	3.92	.787	3.91	72.2
6: I got to know the group members very well.	3.92	.787		67.5
7: We were able to complete the tasks on time.	3.92	.751		69.2
8: I can share my ideas more effectively.	3.91	.815		72.2
9: I am excited that I was able to share my creative ideas and managed to implement them in class.	3.91	.808		70.4
10: I enjoyed the group interaction.	3.88	.788		71.6
Factor 3				
11: I believe I can implement what was learnt from this class activities.	3.86	.779	3.85	76.3
12: I was able to ascertain the relevance between theory and practical implementation through class activities.	3.86	.826		66.9
13: I can currently analyse the essential elements of an idea, experience or theory in-depth, including considering the components more productively.	3.85	.886		66.3
14: I am now able to analyse different perspectives and draw personal deductions.	3.84	.735		72.8
15: Currently I can examine how others gathered and interpreted ideas/information, as well as assess the accuracy of the deductions.	3.83	.924		67.5
16: Presently, I have the ability to apply theories and concepts to practical problems or new situations effectively.	3.83	.824		62.7
Factor 4				
17: I have learned more from collaboration rather than working alone.	3.82	.777	3.81	64.5
18: "My group has taught me things that were challenging to understand personally.	3.81	.886		68.6
19: I feel, I can make decisions more effectively and accurately.	3.81	.831		68.6
20: I have learnt to trust and empower my group members.	3.80	.804		66.9
21: The group tasks helped improve my presentation skills.	3.80	.895		65.7
Factor 5				
22: I believe the knowledge acquired during class activities would be beneficial in the future.	3.74	.921	3.72	78.1
23: I can work more effectively on my own.	3.74	1.013		72.2
24: When I am working individually, I was able to implement the things learnt from group collaboration.	3.69	.709		75.7

Table 5 Factor with mean, STD and Open-Ended Question Responses (Cont.)

Cronbach Alpha .950	
Cronbach Alpha Based on Standardized Items .951	
Selected Survey Items 24	
Student Comments	
1. This trimester, I was motivated to score 4.0 GPA and release my full potential in this course. 2. Working together to solve problems certainly made it easier, plus way more fun. 3. It was awesome because we brought different skills to the table during group activities and helped each other improve. 4. I reckon we would get to know each other even better, as well as enjoy working as a team.	5. I am pretty sure we would learn loads of cool ideas from each other. 6. It blew my mind when knowledge was shared, was excited. 7. When problems were addressed as a group, we have got awesome brainstorming ideas and sharing of opinions. So, we had a lot of options to pick from, and respected whichever was preferable.

This research explored the impact of collaborative game-based learning on student problem-solving abilities, as well as the development of a formal, structured educational community within the classroom. A comprehensive analysis of various data sources, including 169 student questionnaires class activities, pre- and post-tests, as well as assessments, provided valuable insights into the effectiveness of the research. The participants consisted of 88 males and 61 females, and of the 169 students 88 were Malaysian while 8 were foreigners.

The integration of a collaborative educational game into the curriculum helped students practice real-world problem-solving, thereby enhancing the understanding of specific subjects. Simultaneously, it enabled educators to monitor both group and individual student performance, providing necessary support where relevant. The environment improved collaborative thinking and problem-solving skills, motivating students to actively engage in team discussions, share ideas, achieve set objectives, and assist peers effectively.

Educators can offer support to individual needs, and the findings showed that students enthusiastically participated in group discussions, engaging in competitive activities, while contributing diverse solutions and depicting high enjoyment throughout the learning process. In addition, the work samples of the students are shown in Figure 2.

Figure 2 Mobile Application UI/UX designs by students for their final projects

3.5. Student Individual Work

The subsection showcases the impressive creative and innovative mobile application design. Each student undertook a comprehensive individual project in line with market needs and personal interests. This led to the careful acquisition and synthesising of data from diverse sources. The students proposed actionable solutions focused on minimalistic design based on market research. The works outlined a profound grasp of theoretical design concepts, showing the impressive ability to apply the concepts effectively while addressing real-world issues, including providing practical solutions.

3.6 Finding and Discussion

Figure 2 shows the CIGLE framework, a collaborative gaming ecosystem, with the following basic insights.

a. The collaborative game-based method prompted students to be occupied the learning material, making problem-solving central. The findings based on the CIGLE method focused on significant improvements in the capacity for team problem-solving and depth of understanding, depicting improved critical thinking skills. The collaborative process adopted during game and classroom, were properly structured to formulate an engaging environment, including fostering effective group work for positive impact. Botella et al. (2023) reported that collaboration promoted critical thinking and problem-solving skills. Moreover, the heightened motivation of students was evident through active participation and proactive efforts in devising effective solutions.

b. Qualitative analysis and examination of EFA results showed the effectiveness of collaborative games in sustaining student interest and fostering deep engagement with course material. This engagement translated into evident team dynamics, teamwork, and personal development enhancements. The engaging and stimulating gaming environment (Sun et al., 2023) naturally inspired the adoption of critical thinking techniques to overcome obstacles, fostering peer learning and community building within the class.

c. The results of student feedback and survey supported the beneficial effects of CIGLE on learning experiences. According to Fonseca et al. (2023) and Zahra et al. (2023), the game-based learning and community integration strategy effectively motivated students, promoting collaboration, and facilitating teamwork in addressing common challenges. The collaborative nature of this method instilled a sense of mutual responsibility and cooperation.

d. The research stated that students actively initiated discussions on problems introduced within the collaborative gaming environment. This proactive participation deepened the comprehension of the material, facilitating the exchange of ideas and information among students. Meanwhile, through collaborative problem-solving exercises, students developed team strategies, enhancing the readiness to address new challenges.

e. The findings showed significant improvements in knowledge acquisition and critical thinking skills through participation in group activities, which directly benefited individual projects. Moreover, actively engaging in collaborative tasks allowed students to apply the acquired knowledge, exchange perspectives, and collectively address complex challenges, facilitated by effective communication and collaboration within the group environment.

The research proved the substantial effectiveness of the CIGLE framework in enhancing collaborative learning and problem-solving skills. As shown by student performance with structured activities within the gaming environment and physical classroom settings, the CIGLE framework fostered an engaging atmosphere that significantly improved capacities for group work and critical thinking. Moreover, the research showed that students proactively initiated discussions on challenges presented within the collaborative gaming context. This active engagement deepened understanding of the material and also facilitated meaningful exchanges of ideas. The ability to develop team strategies through collaborative problem-solving exercises significantly enhanced the readiness to confront new challenges.

The CIGLE framework exhibited considerable potential to transform contemporary educational practices by properly integrating technology and fostering enhanced collaboration, critical thinking, and active student engagement. Future research should adopt longitudinal methods to thoroughly evaluate the sustained impact of the CIGLE framework, as well as the scalability and applicability across diverse educational settings and academic disciplines. This review strengthened the formal tone, improving the flow, leading to the suitability of academic writing.

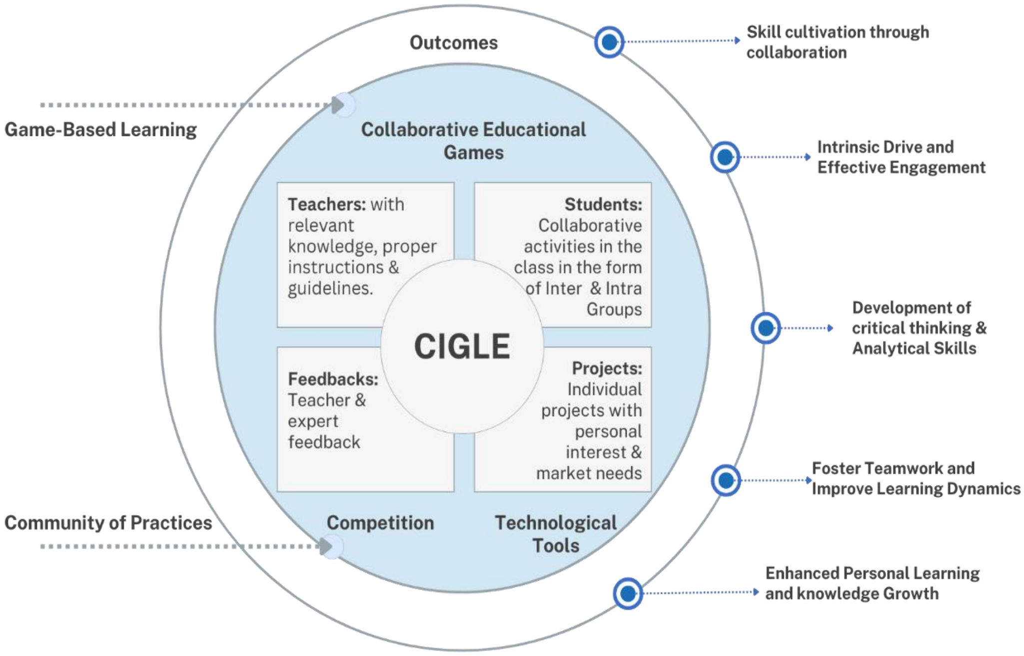

Figure 3 Collaborative and Interactive Game-Based Learning Environment (CIGLE).

4. Conclusions

In conclusion, the research aimed to evaluate the impact of a Collaborative and Interactive Game-Based Learning Environment (CIGLE) on enhancing student learning experiences, focusing on critical thinking, analytical skills, communication, motivation, and collaborative problem-solving while fostering classroom learning communities. This was achieved by integrating GBL principles and CoP into the classroom. The findings robustly supported the effectiveness of this redesigned framework for educational settings. By incorporating collaborative and challenging activities both in the classroom and through games, the research effectively enhanced student collaborative problem-solving and critical thinking abilities, thereby developing individual skill sets. Interactive gameplay motivated students to address complex problems, analyse information, and devise innovative solutions, thereby enhancing cognitive capacities, while promoting teamwork and communication skills. Moreover, CIGLE naturally stimulated curiosity, inspiring active engagement and immersion in learning. The challenging nature of game-based learning captured student interest, resulting in the motivation to explore and deepen understanding of the subject matter. As a result, learners became more invested in the journey, enhancing overall learning outcomes and personal growth. The research showed how CIGLE improved student performance and enhanced the classroom atmosphere. It further proved that challenging and collaborative learning environments significantly enhanced critical thinking, problem-solving abilities, and active participation in education. These findings offered valuable insights for educators seeking to create effective learning environments for the cultivation of 21st-century skills and community-driven learning through the integration of CoP within a collaborative gaming ecosystem.

5. Study Limitation and Future Direction

Certain limitations need to be taken into account, despite providing insightful information about the efficacy of the CIGLE framework. Firstly, a relatively small sample size allowed for a detailed analysis of the unique learning style of each participant during the research. The results cannot be applied to larger courses or more diverse student populations due to the small sample size. Secondly, the research was carried out in small and multiple batches over a limited period of time, giving a brief overview of the framework effects. The adoption of longitudinal method would be necessary to evaluate the long-term impacts and wider advantages of CIGLE on academic performance. Inequalities in student access to technology and differing degrees of digital literacy also presented difficulties, outlining the need for fair resource distribution and sufficient training.

Moreover, the future research should extend the duration to evaluate the long-term effects of the CIGLE framework on a large sample size for multiple subjects to enable generalization at a wider scale. The integration with advanced technologies such as AR/VR could enhance student engagement. In order to effectively implement the CIGLE framework, comprehensive instructor training programs are essential for both students and teachers. The use of diverse assessment tools, application of the framework to different subjects, and gathering of structured student feedback helped evaluate the framework thoroughly. This method also supported the ongoing improvements, leading to better learning outcomes.

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Author Contributions

IZ contributed in developing the research topic, planning and strategizing the game learning environment, the methodology, data analysis and preparing the manuscript.

MN contributed towards the pedagogy of the study while SHH contributed towards the data collection process. Before finalising the work, all authors evaluated and approved the results.

Conflict of Interest

The authors declare no conflict of interest.

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