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Exploring the Influence of Interpersonal Relationships on Gamification Preferences in Collaborative IVR Environments

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Figure 1: Overview of the gamification design concept in immersive virtual reality environments, focusing on a collaborative learning-based game intended to improve teamwork and social engagement among participants, regardless of their level of acquaintance.

Abstract

Recent advancements in immersive virtual reality (IVR) have highlighted its expanding potential in educational settings. However, the influence of learners' interpersonal relationships on their preferences for gamification elements in collaborative environments remains underexplored. This study introduces an avatar-based multiplayer IVR game designed to promote collaborative learning through improved social interaction. The game features a maze with three challenging puzzles, which require teamwork and problem-solving skills, encouraging communication and information sharing among participants. In addition, the study investigates the impact of different gamification elements on groups consisting of either peers or strangers, involving a total of 44 participants. The findings revealed significant improvements in communication and collaboration skills, along with increased motivation and engagement, across both group types. Moreover, participants exhibited distinct preferences for specific gamification elements, largely influenced by the nature of their social relationships and individual tendencies. This study offers valuable insights into the design of IVR-based collaborative educational environments with an emphasis on social interaction and game mechanics. It also identifies key factors shaping individual preferences for gamification elements, particularly in relation to social dynamics and personal preferences.

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1 Introduction

This study explores the impact of interpersonal relationships on preferences for gamification in collaborative immersive virtual reality (IVR) environments. A multiplayer avatar-based IVR game that features a maze with three puzzles was designed to improve teamwork, communication, and problem solving. The study involved 44 participants, exploring how gamification elements influenced groups of peers versus strangers. The results showed significant improvements in communication, collaboration, motivation, and engagement in both types of groups. The participants' preferences for gamification elements varied according to social relationships and individual characteristics. These findings provide insights into designing IVR-based collaborative learning environments that emphasize social interaction and custom game mechanics.

In the era of Education 4.0, the integration of emerging technologies has become essential to transform the educational landscape, influencing the skills, attitudes, and values necessary for future teaching and learning practices [30]. Among these technologies, immersive virtual reality (IVR) has gained widespread popularity due to its interdisciplinary potential to revolutionize both teaching and learning. IVR offers an unprecedented way of engaging students, allowing them to experience learning in new and innovative formats [48]. Studies have shown that the integration of IVR in experiential and topical learning significantly improves soft skills, communication abilities, and critical thinking skills of students [5].

The concept of gamification refers to the integration of specific components of game design into non-gaming environments to increase engagement and learning [18], such as in escape rooms [38, 3]. This involves utilizing game mechanics and principles to enhance educational experiences and is noted for its ability to increase student motivation, engagement, and learning outcomes [52]. Implementing these specific game elements, such as goal setting, role definition, and structured feedback, has shown improvements in self-efficacy and learning outcomes, making education more interactive and enjoyable in different disciplines [36]. Various psychological learning theories suggest that gamified strategies, by representing complex and abstract concepts in interactive virtual formats, create an engaging environment that promotes deeper student interest and effectively capture and sustain learners' attention and motivation [9].

Previous studies on social interaction in IVR focused mainly on how it enhances collaborative learning, fosters emotional development, and reduces the social distance inherent in online learning [59]. To design more effective IVR learning strategies, the elements of the game were categorized according to their potential to stimulate intrinsic or extrinsic motivation [37, 43]. Collaboration among peers is also known to increase motivation by fostering a sense of shared goals and social engagement [50]. Although prior research has quantified the overall effectiveness of gamification strategies in IVR learning, revealing improvements in student motivation, engagement, and performance [51, 45, 44], few studies have examined the specific impact of group learning in a gamified IVR setting. To address this gap, this study investigates the design of gamification strategies in multiplayer IVR environments and evaluates the effects of collaborative learning on motivation, engagement, and performance.

Specifically, this study explores the integration of gamification in IVR settings for undergraduate and postgraduate students, focusing on how different game elements influence the intrinsic motivation and extrinsic motivation of students during collaborative learning. The aim is to understand the connections between various game elements and their impact on improving the quality of collaboration in IVR-based learning environments. This study also explores the design of game mechanics in various mini-games within IVR settings to improve student social interactions, offering insights for researchers and educators to develop gamification strategies as collaborative tools in IVR environments. Three core factors were addressed: social interaction, intrinsic motivation, and extrinsic motivation.

This work aims to answer the following key questions:

- RQ1: How do gamification elements in an IVR learning environment influence intrinsic and extrinsic motivations during collaborative learning, and what are the differences when learning with a peer versus a stranger?
- RQ2: How do gamification elements in an IVR learning environment affect the overall user experience, particularly regarding the impact of social interaction on learning outcomes when collaborating with a peer versus a stranger?

2 Related Work

Lampropoulos *et al.* [36] provided a comprehensive review of various gamification mechanisms employed in IVR educational environments, based on an analysis of 112 scholarly articles. These mechanisms focused primarily on game-like features, including mechanics, points, and quizzes. Bahrin *et al.* [8] explored the role of gamification in improving enjoyment and supporting informal learning within IVR settings, concluding that such elements significantly increase user engagement and motivation to learn. Similarly, Jagušt *et al.* [32] examined the impact of point and reward systems in mathematics education, finding that they promoted interaction and knowledge sharing among learners in group settings, thus fostering communication and collaborative skills. Their research highlighted the potential of gamification in creating multiplayer interactive VR learning environments.

Psychological and social elements greatly affect how learners engage and behave in immersive, game-based settings. Self-determination theory (SDT) suggests that satisfying learners' needs for autonomy, competence, and relatedness increases intrinsic motivation [50, 17]. In collaborative learning with IVR, adding asynchronous tasks and different roles can increase this intrinsic motivation [16]. In addition, the Bandura study [10] shows that the theory of social learning emphasizes modeling, observational learning, and feedback to influence group dynamics. Strategically integrating information asymmetry improves knowledge sharing and strengthens team cohesion through peer guidance and observation [33]. Social constructivism considers knowledge as an outcome of effective collaboration and dialogue [57]. In general, the game elements that promote mutual assistance and collaborative problem-solving can improve social cohesion and learning in IVR settings.

Further investigation by L'opez-Faican and Jaen [39] revealed that multiplayer gaming scenarios in primary education yielded more substantial positive effects on emotional bonding, social interaction, and interest in cooperative game modes compared to competitive ones. Bouchrika *et al.* [14] studied the influence of gamification on student engagement over a 10-month period, concluding that gamification effectively attracted learners and improved interaction within educational contexts. Similarly, Alsawaier [4] stated the positive impact of game elements on learning motivation and engagement, particularly in addressing declining student participation. However, these studies showed significant research gaps in the transformation of gamification theory into practical guidelines for its implementation.

In mathematics education, Thomsen *et al.* [55] and Drey *et al.* [19] reported improved cooperative learning and motivation when comparing asymmetrical and symmetrical IVR teaching methods, respectively. Becerra *et al.* [13] successfully used gamification to simplify complex physical concepts, enhancing students' exploratory behaviors and independent learning skills. Likewise, Nicola *et al.* [46] emphasized the advantages of integrating gamification elements in the teaching of complex algorithms, noting increased student interest and interaction. Furthermore, Mayer [41] studied team dynamics within a digital game setting, supporting the internal validity of in-game assessments in team research and highlighting the importance of team cohesiveness. While these studies have demonstrated the advantages of immersive gamified education, there is limited research on how gamification differentially affects diverse learner profiles, especially in multiplayer educational environments. Specifically, our method uniquely uses IVR-based, asymmetric learning tasks to examine the impact of specific game elements on intrinsic and extrinsic motivations in multiplayer settings.

A significant body of research has highlighted the beneficial aspects of applying gamification in IVR education. Nevertheless, there is a notable gap in understanding how gamification affects team-based versus individual learning experiences. Wilson *et al.* [58] found that gamification elements, such as points, badges, leaderboards, and storytelling, enhanced the appeal of virtual learning environments, providing instant feedback and rewards that increased engagement and satisfaction. Reitz *et al.* [49] demonstrated that gamification elements such as points, tasks, levels, and virtual rewards significantly improved social interaction skills among learners. Meanwhile, Hamari *et al.* [26] explored the positive effects of rewards and leaderboards on extrinsic motivation in team learning, but also noted the more complex impact of these elements on intrinsic motivation.

Seaborn and Fels [52] discussed how storytelling and immersion within gamified environments can improve intrinsic motivation by increasing learners' interest and engagement. Henriksen *et al.* [27]

examined how technology in educational settings supports creative risk taking and productive failure, promoting innovation and active learning. Furthermore, Huang *et al.* [29] found that animations and puzzles in gamified environments promoted cognitive and emotional engagement by offering visual stimuli and dynamic content, thus improving problem solving satisfaction and intrinsic motivation. Lucarevschi and Claudio [40] noted that storytelling in teaching not only increased learning fun and interaction, but also helped students emotionally connect with the content, increasing their intrinsic motivation.

Adams *et al.* [2] demonstrated that role-playing within narrative structures deepened learners' engagement, helping them form long-term memory and understanding of the learning material. Arsenopoulou *et al.* [7] observed immersive character performances and visual effects in games like "Batman: Arkham" deepened the emotional connection of players to the world of the game. Despite these insights, few studies have explored the specific impact of gamification elements on multiplayer learning environments. This study uses principles of educational psychology and social learning theory to connect interpersonal relationships, team cohesion, and effective learning, to create gamification strategies focused on improving interdisciplinary problem solving and promoting asymmetric learning. The main objective is to improve interactions among diverse teammates during learning and inspect which gamification components increase intrinsic and extrinsic motivations.

3 Methodology

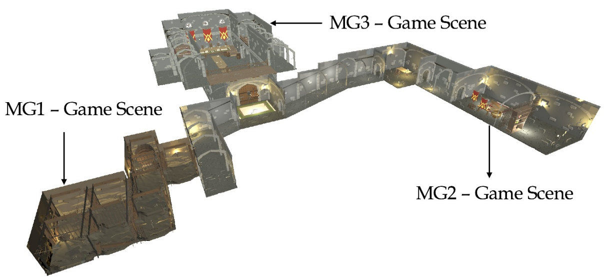


Figure 2: Overview of the SC-IVRG design based on the escape room (dungeon maze) theme, where students collaborated to solve academic problems in the mini-games to escape the dungeon.

This study created a dungeon escape game that included three mini-games: the Zoology Ring Puzzle (refer to Section 3.1), Arithmetic Potion Maker (see Section 3.2) and Geometry Cryptex (see Section 3.3). Following the Octalysis game design framework [20], 17 theoretically important game elements were selected to improve social interaction and collaborative learning. Table 1 presents these game elements and their associations with each mini-game. The social interaction collaborative learning-based IVR game (SC-IVRG) was designed with an escape room (dungeon maze) theme. The design of the dungeon maze, which is depicted in Fig. 2, featured the three mini-games placed at different locations within the maze. In this setting, two players, represented by avatars of a fox and a rabbit, were required to collaborate by engaging in communication, discussion, and information sharing to solve academic problems designed within the mini-games. Successfully finishing the mini-games would allow them to leave the dungeon maze. The dungeon escape game was developed with Unity3D development platform [56] and deployed on the Meta Oculus Quest 3 [1].

3.1 Mini-Game 1: Zoology Ring Puzzle

Mini-game 1 integrated 13 game elements and was based on zoological knowledge, specifically focusing on animal behaviors and

Table 1: Description of selected game elements based on the Octalysis framework [54], focusing on promoting social interaction and improving learning experiences in the IVR learning environment, along with their associations with each mini-game and motivation types

Category	Game Element	Motivation
Social Interaction	Collaboration[1,2,3]	Extrinsic
Accomplishment	Level[1] Mission[2,3]	Extrinsic Extrinsic
Autonomy	Freedom to Fail[1,2,3] Non-Linear Navigation[2,3]	Intrinsic Extrinsic
Curiosity	Unpredictable Event[2,3]	Intrinsic
Immersion	VR Headset[1,2,3] Animation[1,2] Audio Effect[1,2,3] Haptic Feedback[1]	Intrinsic Intrinsic Extrinsic Extrinsic
Narrative	Storytelling[1,3] Role-Play[1,2,3] Cinematic Scene[1,2,3] Guide[1,2,3]	Intrinsic Intrinsic Intrinsic Extrinsic
Ownership	Avatar[1,2,3] Virtual Good[2,3]	Extrinsic Extrinsic
Challenge	Puzzle[1]	Intrinsic

[1] Game element implemented in mini-game 1
[2] Game element implemented in mini-game 2
[3] Game element implemented in mini-game 3

habitats. In this mini-game, both players, represented by their respective avatars, were confined to separate cells. Each player had access to a ring puzzle located at the back of their locked cell, beneath which animal-related information was provided (see Fig. 3a). The information available to player A (see Fig. 3b) was actually the key to solving player B's (see Fig. 3c) puzzle, and vice versa, following the "view asymmetry" design concept. This game mechanic emphasized communication and social interaction, which drove players to share unique information about their puzzle, thus encouraging collaboration.

The cooperative aspect of this gamified learning task was fueled by data asymmetry, with unique information that prompts participants to collaborate and emulate game-driven behaviors, improving communication. Mini-game 1 also drew on the theory of social learning, allowing players to learn by observing and interacting with others [11]. This interdependent model, which required players to exchange clues to solve their puzzles, blended problem solving with social interaction [25].

Each ring puzzle featured three animal-related clues that required three correct rotations of the ring, with the red pointer marking the correct animal based on the information provided. In addition, animated and visual effects were integrated [42] to improve engagement and memory retention. If the players did not provide the correct animal within a set time frame, additional hints and clues were offered as guidance.

3.2 Mini-Game 2: Arithmetic Potion Maker

Mini-game 2 integrated arithmetic knowledge of cubic equations within the alchemist potion-making theme, using 13 game elements (see Fig. 4a). This mini-game applied mathematical concepts in a practical and interactive setting, with the aim of promoting a deeper

(a)

(b)

(c)

Figure 3: Design of mini-game 1, illustrating (a) the two ring puzzles located at the back of the locked cells, accessible only to the player in that cell, and the views of the animal information provided under the puzzles for (b) player A and (c) player B.

understanding and enhancing memory retention through hands-on experience, consistent with the principles of active and social learning [57]. The game was designed to encourage collaborative learning and social interaction, where a player combined different liquids in precise amounts to make a potion on a table (see Fig. 4b). However, the required amounts were only accessible to another player located in a locked cell, where cubic equations were displayed on a shelf that could only be viewed by that player (see Fig. 4c).

In order to access the locked cell, one player needed to stand on a stone platform, which opened the cell door. Stepping off the stone caused the door to close. This mechanic virtually separated the players, placing them in different virtual positions, and necessitated communication to share the information required to solve the equations for potion creation. The design followed the concept of "movement asymmetry", encouraging players to rely on each other's information in different positions to solve the game task.

3.3 Mini-Game 3: Geometry Cryptex

Mini-game 3 was designed to improve geometric and spatial visualization skills, emphasizing abstract abilities such as symmetry and image rotation. It integrated 13 game elements in the form of a Cryptex, with the goal of improving players' comprehension of symmetry, rotation, and shape matching, particularly useful in subjects related to architecture and engineering. The mini-game allowed both players to manipulate virtual blocks where each of the blocks had different image patterns on four sides. The objective was to match the patterns of the virtual blocks (block-to-block) with those on the left and right sides, as shown in Fig. 5a.

The challenge intensified as the number of blocks increased, making it more difficult to correctly position the blocks and match the patterns on both sides. player A could see the static block on the far left side (hidden from player B, see Fig. 5b), while player B could view the block on the far right side (hidden from player A, see Fig. 5c), following the "view asymmetry" design concept. This

(a)

(b)

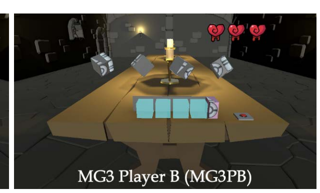
(c)

Figure 4: Design of mini-game 2, illustrating (a) the potion-making scenario requiring (b) one player to mix the potion at the table, and (c) another player to derive the correct liquid amounts by solving the cubic equation in a locked cell.

game mechanic required players to collaborate to solve the puzzle, exchanging information about the block patterns visible to them.

(a)

(b)



(c)

Figure 5: Design of mini-game 3, illustrating (a) the task of completing the Cryptex by placing the virtual blocks in the correct position, aligning the patterns to match those on both the left and right sides of the blocks, where (b) the leftmost block is only visible to player A, and (c) the rightmost block is only visible to player B.

Table 2: Demographic information of the participants

Group	Player A (PA) ID	Age	Faculty	Personality	Player B (PB) ID	Age	Faculty	Personality
Peer	01-PA	24	Business School	Extrovert	01-PB	23	Business School	Extrovert
	02-PA	21	Sciences & Engineering	Introvert	02-PB	22	Sciences & Engineering	Introvert
	05-PA	20	Sciences & Engineering	Extrovert	05-PB	22	Sciences & Engineering	Introvert
	07-PA	21	Sciences & Engineering	Extrovert	07-PB	20	Business School	Extrovert
	08-PA	22	Business School	Introvert	08-PB	24	Sciences & Engineering	Extrovert
	09-PA	21	Sciences & Engineering	Introvert	09-PB	21	Business School	Extrovert
	10-PA	20	Humanities & Social Sciences	Introvert	10-PB	22	Sciences & Engineering	Extrovert
	11-PA	24	Sciences & Engineering	Extrovert	11-PB	25	Humanities & Social Sciences	Introvert
	13-PA	20	Humanities & Social Sciences	Introvert	13-PB	25	Humanities & Social Sciences	Extrovert
	21-PA	20	Humanities & Social Sciences	Extrovert	21-PB	19	Humanities & Social Sciences	Extrovert
	22-PA	21	Humanities & Social Sciences	Extrovert	22-PB	21	Humanities & Social Sciences	Introvert
Stranger	03-SA	21	Sciences & Engineering	Introvert	03-SB	20	Sciences & Engineering	Extrovert
	04-PA	21	Sciences & Engineering	Introvert	04-PB	20	Sciences & Engineering	Introvert
	06-PA	19	Sciences & Engineering	Introvert	06-PB	21	Sciences & Engineering	Extrovert
	12-PA	19	Humanities & Social Sciences	Introvert	12-PB	24	Sciences & Engineering	Extrovert
	14-PA	23	Humanities & Social Sciences	Introvert	14-PB	25	Humanities & Social Sciences	Introvert
	15-PA	24	Business School	Extrovert	15-PB	24	Sciences & Engineering	Extrovert
	16-PA	24	Humanities & Social Sciences	Extrovert	16-PB	23	Humanities & Social Sciences	Extrovert
	17-PA	24	Business School	Extrovert	17-PB	24	Business School	Extrovert
	18-PA	20	Business School	Extrovert	18-PB	20	Humanities & Social Sciences	Extrovert
	19-PA	20	Business School	Extrovert	19-PB	20	Humanities & Social Sciences	Extrovert
	20-PA	21	Business School	Extrovert	20-PB	22	Humanities & Social Sciences	Extrovert

4 EXPERIMENT SETUP

4.1 Participants and Experiment Design

A total of 44 undergraduate and postgraduate students, aged 19 to 25 years ($\mu_{age} = 21.68$, $\sigma_{age} = 1.74$), were recruited for the study. Participants were randomly selected from three different majors, including business, sciences & engineering and social sciences using a random sampling approach. They were categorized into two main groups: the peer group (PG), where both students were familiar with each other, and the stranger group (SG), where the participants met for the first time. The groups included 11 teams, with only four participants reporting experiencing VR games. Table 2 presents the demographic information of the participants, including self-assessed personality types (27 extroverts and 17 introverts).

Before the experiment, the participants were briefed on the tasks and provided their signed consent form. They then received a 15-minute training session to familiarize themselves with the basic operations of the IVR game, including the use of the VR headset and controllers. Participants were informed of their right to withdraw from the study at any time if they felt uncomfortable. The experiment was carried out in a room that provided sufficient mobility space for the two participants to participate in the SC-IVRG, which lasted approximately one hour. After playing, the participants took a five-minute break and were asked to complete self-rating questionnaires for data collection. This was followed by a short interview lasting around 20 minutes to gather detailed feedback. The overview of the experiment design is shown in Fig. 6.

The procedure was approved by the Research Ethics Commitee of the Faculty of Science and Engineering of the University of Nottingham Ningbo China.

4.2 Self-Rating Questionnaires

The experimental design and the selection of measurement instruments for the analysis of the results are based on well-established frameworks and methods from state-of-the-art studies [39, 28, 23, 53]. In this study, two different self-rating questionnaires were used: the Game Experience Questionnaire (GEQ) [31] and the Instructional Materials Motivation Survey (IMMS) [35]. The GEQ, known for its established psychometric properties, was utilized to evaluate player gaming experiences in IVR environments [60]. It comprises 33 items grouped into seven dimensions: perceived immersion, fluency, tension, challenge, emotional experience, fatigue, and self-efficacy. These items were further categorized into four modules: core, in-game, social presence, and post-game. For the purposes of this study, the core, social presence and post-game modules were used to gain insight into the cognitive, emotional, and behavioral experiences of students during the game.

The core module of the GEQ evaluated seven components: immersion, flow, competence, positive affect, negative affect, tension, and challenge. The social presence module included three components: psychological involvement through empathy, psychological involvement characterized by negative emotions, and behavioral involvement. Psychological involvement through empathy (items 1, 4, 8, 9, 10, and 13) measured players' sense of connection, empathy, and the sharing of positive emotions. Psychological involvement characterized by negative emotions (items 7, 11, 12, 16, and 17) captured feelings such as jealousy, revenge, schadenfreude, or emotional contagion. Behavioral involvement (items 2, 3, 5, 6, 14, and 15) evaluated the level of attention and influence among teammates, including mutual dependence and admiration. The post-game module assessed four components: positive experience, negative experience, tiredness, and returning to reality.

In addition, IMMS was adopted to measure the effect of SC-IVRG on participant learning motivation, with its validity supported by psychometric evaluations [15]. The IMMS contained 29 items spread across four dimensions: confidence, attention, satisfaction, and relevance. On the other hand, a Game Elements Ranking Scale (GERS) was developed that allowed participants to rate their perceptions of the game elements implemented in SC-IVRG. The GERS included a total of 17 items corresponding to the game elements implemented. Each item in the GEQ, IMMS and GERS was rated on a 5-point Likert scale.

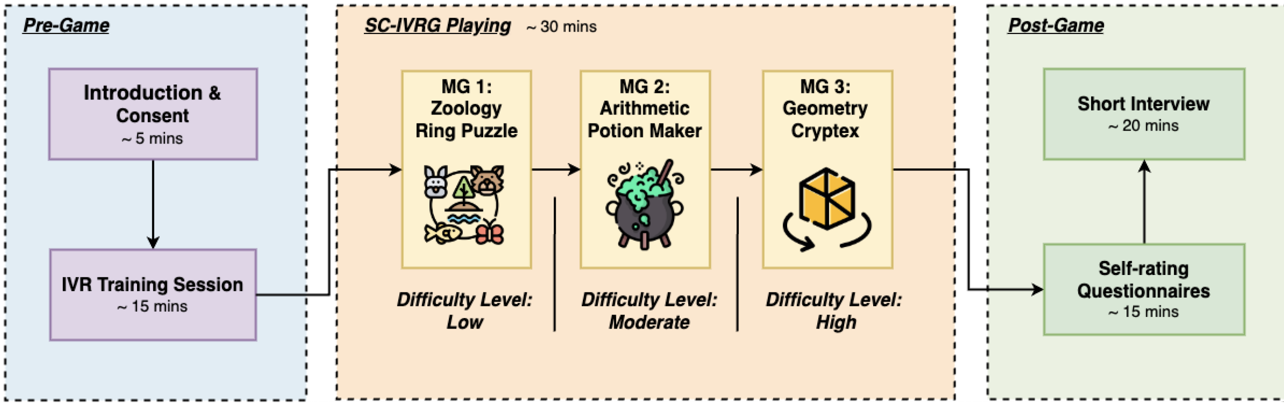


Figure 6: Overview of the experimental setup, divided into three phases: the pre-game phase, where participants were introduced to the study and received an IVR interaction tutorial; the SC-IVRG gameplay phase, during which both participants collaborated to solve three game tasks; and the post-game phase, where participants completed a self-rating questionnaire followed by a brief interview with the researchers.

5 Results

5.1 GEQ

Table 3 presents the mean scores and results of independent samples t-tests for the three main modules of the GEQ: core, social presence and post-game.

5.1.1 Core Module

Participants generally reported low mean scores in the tension component ($\mu = 0.598$, $\sigma = 0.732$), without significant differences ($t = 1.173$, $p = 0.248$) between the participants in SG ($\mu = 0.727$, $\sigma = 0.833$) and in PG ($\mu = 0.470$, $\sigma = 0.606$). In the negative affect component, all participants provided similarly low scores ($\mu = 0.960$, $\sigma = 0.889$), with no significant differences ($t = 0.717$, $p = 0.478$) between participants in SG ($\mu = 1.057$, $\sigma = 1.060$) and in PG ($\mu = 0.864$, $\sigma = 0.689$). In contrast, the participants highly rated the positive affect component, with a mean overall score of $\mu = 2.882$, $\sigma = 0.247$, although no significant differences ($t = -1.807$, $p = 0.078$) were detected between the participants in SG ($\mu = 2.809$, $\sigma = 0.329$) and in PG ($\mu = 2.955$, $\sigma = 0.184$).

A significant difference ($t = -5.342$, $p < 0.001$) was observed in the competence component, where participants in PG ($\mu = 3.264$, $\sigma = 0.340$) scored significantly higher than in SG ($\mu = 2.618$, $\sigma = 0.453$), suggesting a notable variation in the perceived level of skill between groups. Similarly, participants reported high scores in sensory and imaginative immersion ($\mu = 2.867$, $\sigma = 0.214$), with participants in PG scoring higher ($\mu = 2.932$, $\sigma = 0.176$) than in SG ($\mu = 2.803$, $\sigma = 0.234$), indicating statistical significance ($t = -2.067$, $p = 0.045$). Furthermore, the flow component produced an overall mean score of $\mu = 2.950$, $\sigma = 0.296$, with participants in PG scoring higher ($\mu = 3.073$, $\sigma = 0.330$) than in SG ($\mu = 2.827$, $\sigma = 0.198$), a statistically significant difference ($t = -2.993$, $p = 0.005$).

Finally, the challenge component revealed a lower overall mean score ($\mu = 1.536$, $\sigma = 0.629$), with participants in PG reporting lower scores ($\mu = 1.345$, $\sigma = 0.651$) compared to those of SG ($\mu = 1.727$, $\sigma = 0.557$), indicating a statistically significant difference ($t = 2.090$, $p = 0.043$).

5.1.2 Social Presence Module

The findings indicated that the participants generally showed a moderate level of empathy toward their teammates, with an overall mean of $\mu = 3.105$, $\sigma = 0.459$. PG participants showed slightly higher empathy ($\mu = 3.164$, $\sigma = 0.551$) compared to SG participants ($\mu = 3.045$, $\sigma = 0.436$). Regarding psychological involvement characterized by negative emotions, participants reported low levels of negative feelings ($\mu = 1.091$, $\sigma = 0.722$). Participants in SG experienced fewer negative emotions ($\mu = 0.955$, $\sigma = 0.679$) than those in PG ($\mu = 1.091$, $\sigma = 0.722$). Lastly, the overall mean score for behavioral involvement was relatively high ($\mu = 3.062$, $\sigma = 0.628$), indicating strong behavioral involvement within the groups. PG participants exhibited greater behavioral involvement ($\mu = 3.110$, $\sigma = 0.628$) compared to SG participants ($\mu = 2.948$, $\sigma = 0.474$).

5.1.3 Post-Game Module

Participants in both PG and SG reported high levels of enjoyment and engagement in the positive experience component, with an overall $\mu = 3.337$ and $\sigma = 0.395$. PG participants presented $\mu = 3.356$ and $\sigma = 0.365$, while SG participants reported $\mu = 3.318$ and $\sigma = 0.430$, without significant differences between the two groups ($t = -0.315$, $p = 0.435$). Similarly, the negative experience component showed low overall scores ($\mu = 0.598$, $\sigma = 0.239$), with minimal variation between the participants in PG ($\mu = 0.561$, $\sigma = 0.189$) and SG ($\mu = 0.636$, $\sigma = 0.280$) and no significant differences between them ($t = 1.051$, $p = 0.299$). This suggests that negative emotional responses to the game were comparable to those of the group, regardless of group familiarity.

For the tiredness component, participants generally reported low levels of fatigue, with $\mu = 0.625$ and $\sigma = 0.484$. Participants in PG showed marginally lower fatigue ($\mu = 0.545$, $\sigma = 0.375$) compared to SG ($\mu = 0.705$, $\sigma = 0.570$); however, this difference was not statistically significant ($t = 1.093$, $p = 0.281$).

However, a significant difference emerged in the returning to reality component, where participants in PG ($\mu = 2.394$, $\sigma = 0.579$) found it more difficult to disengage from the gaming environment and re-enter real-world contexts compared to SG ($\mu = 2.818$, $\sigma = 0.445$), with the difference being statistically significant ($t = -2.726$, $p = 0.009$). This suggests that social familiarity can increase immersion, making it harder for participants in PG to transition back to reality after the game is over.

5.2 IMMS

Table 4 displays the mean IMMS scores and the results of the independent samples t-tests for the four dimensions. The participants generally performed well in the attention dimension, with $\mu = 3.026$ and $\sigma = 0.660$. There were no significant differences in attention between participants in PG ($\mu = 2.981$, $\sigma = 0.790$) and in SG ($\mu = 3.071$, $\sigma = 0.514$), with $t = 0.452$ and $p = 0.654$. The educational content was considered highly relevant by all participants,

Table 3: GEQ results, including mean scores (μ) and standard deviations (σ), along with independent samples t-tests (*$p < .05$, **$p < .01$, ***$p < .001$) for three modules (core (CR), social presence (SP) and post-game (PT)) across 14 components, were assessed for both the stranger group (SG) and peer group (PG)

Module	Component	SG+PG μ (σ)	SG μ (σ)	PG μ (σ)	t-value	p-value
CR	Competence	2.941 (0.513)	2.618 (0.453)	3.264 (0.340)	-5.342	<0.001***
	Sensory and Imaginative Immersion	2.867 (0.214)	2.803 (0.234)	2.932 (0.176)	-2.067	0.045*
	Flow	2.950 (0.296)	2.827 (0.198)	3.073 (0.330)	-2.993	0.005**
	Tension	0.598 (0.732)	0.727 (0.833)	0.470 (0.606)	1.173	0.248
	Challenge	1.536 (0.629)	1.727 (0.557)	1.345 (0.651)	2.090	0.043*
	Negative Effect	0.960 (0.889)	1.057 (1.060)	0.864 (0.689)	0.717	0.478
	Positive Effect	2.882 (0.247)	2.809 (0.329)	2.955 (0.184)	-1.807	0.078
SP	Psychological Involvement - Empathy	3.105 (0.459)	3.045 (0.436)	3.164 (0.551)	-0.789	0.435
	Psychological Involvement - Negative Feeling	1.901 (0.722)	0.955 (0.679)	1.227 (0.754)	-1.261	0.214
	Behavioral Involvement	3.062 (0.628)	2.948 (0.474)	3.110 (0.628)	-0.968	0.339
PT	Positive Experience	3.337 (0.395)	3.318 (0.430)	3.356 (0.365)	-0.315	0.435
	Negative Experience	0.598 (0.239)	0.636 (0.280)	0.561 (0.189)	1.051	0.299
	Tiredness	0.625 (0.484)	0.705 (0.570)	0.545 (0.375)	1.093	0.281
	Returning to Reality	2.606 (0.553)	2.394 (0.579)	2.818 (0.445)	-2.726	0.009**

with overall relevance $\mu = 2.739$ and $\sigma = 0.704$. The mean scores of relevance for the participants in PG ($\mu = 2.761$, $\sigma = 0.787$) and SG ($\mu = 2.716$, $\sigma = 0.629$) did not show statistically significant differences ($t = -0.212$, $p = 0.833$).

In contrast, the confidence levels in solving the game puzzles were relatively high ($\mu = 2.932$, $\sigma = 0.576$), but the participants in PG exhibited significantly greater confidence ($\mu = 3.142$, $\sigma = 0.463$) compared to the participants in SG ($\mu = 2.722$, $\sigma = 0.610$), as indicated by statistically significant $t = -2.575$ and $p = 0.014$. Similarly, satisfaction levels were generally high for both groups ($\mu = 3.118$, $\sigma = 0.674$). However, participants in PG reported significantly higher satisfaction ($\mu = 3.345$, $\sigma = 0.521$) compared to participants in SG ($\mu = 2.891$, $\sigma = 0.743$), reflected by significant $t = -2.351$ and $p = 0.024$.

5.3 GERS

Table 5 presents the GERS results, ranking game elements from highest to lowest according to the overall mean score using the Borda count method [22]. The five elements of the game with the highest mean scores were "VR headset" ($\mu = 3.545$), "collaboration" ($\mu = 3.523$), "mission" ($\mu = 3.477$), "level" ($\mu = 3.227$) and "puzzle" ($\mu = 3.182$). Surprisingly, the game elements rated with the lowest mean scores included "freedom to fail" ($\mu = 2.273$), "storytelling" ($\mu = 2.182$), "cinematic scene" ($\mu = 1.841$), "audio effect" ($\mu = 1.750$), and "animation" ($\mu = 1.705$). These findings suggest that participants perceived these five lower-ranked game elements to contribute less to social interaction and collaborative learning in IVR environments.

In particular, participants in the SG rated "avatar" ($\mu = 3.364$) and "role-play" ($\mu = 3.318$) game elements significantly higher than those of the PG, implying that unfamiliar teammates relied on character roles and virtual appearances as initial points of interaction. The "guide" game element ($\mu = 3.227$) also received higher ratings from participants in SG, indicating their dependence on in-game guidance to promote social interaction. Interestingly, the "freedom to fail" game element ($\mu = 2.682$) was rated higher in SG participants compared to participants in both SG+PG and PG, which means that participants in SG favored the trial-and-error mechanism, which gave them more opportunities to restart the game without much argument or discussion. This mechanism also helped the participants in the SG develop a deeper mutual understanding during problem-solving discussions.

In contrast, PG participants scored a higher mean score in the "unpredictable event" game element ($\mu = 3.409$) than participants in SG+PG and SG, suggesting that familiar team members derived more enjoyment from this aspect. This is further supported by the higher mean score for the "puzzle" game element in the PG participants compared to the SG participants. However, participants in PG rated the "guide" ($\mu = 2.227$) and "freedom to fail" ($\mu = 1.864$) game elements lower than those of SG, suggesting that when working with familiar teammates, they relied less on third-party guidance and were less concerned with communication issues, such as arguments or disagreements, during problem-solving discussions.

5.4 Qualitative Analysis

Qualitative feedback highlighted communication, patience, and adaptability as essential for effective collaborative problem-solving. Challenges occurred when working with unfamiliar team members, particularly in expressing ideas clearly. Some participants found that adapting communication strategies improved their sense of achievement. One participant described the activity as a "significant test" of communication skills, which could promote more intentional and effective interactions. Teams with introverted members needed more time to achieve mutual understanding, but showed remarkable patience and felt fulfilled after achieving it. Similarly, while extrovert-type participants initially hesitated, engagement and role differentiation developed over time, improving interaction and team unity. Most of the participants felt more comfortable and motivated in open, low-pressure communication environments. Importantly, several teams remained in contact after the experiments, suggesting that the IVR experience could serve as an effective icebreaker, promoting lasting social connections.

These findings correlate with theoretical models [10, 33, 50, 17] emphasizing social interaction, observational learning, and psychological safety in collaborative learning. Participants in SG gradually overcome communication barriers through patience, feedback and adaptive roles, which illustrate the focus of social learning theory on mutual support. The reports of better coordination and increased achievement of the participants align with educational psychology, which notes that meeting learners' needs for autonomy, competence, and relatedness promotes intrinsic motivation. This was significantly clear when participants explained complex ideas in various ways, which improved their understanding and helped their peers. Many felt comfortable and joyful, indicating that

Table 4: IMMS results, including mean scores (μ) and standard deviations (σ), along with independent samples t-tests ($*p < .05$) for four dimensions across 29 items, were assessed for both the stranger group (SG) and peer group (PG)

Dimension	SG+PG μ (σ)	SG μ (σ)	PG μ (σ)	t-value	p-value
Confidence	2.932 (0.576)	2.722 (0.610)	3.142 (0.463)	-2.575	0.014*
Attention	3.026 (0.660)	3.071 (0.514)	2.981 (0.790)	0.452	0.654
Satisfaction	3.118 (0.674)	2.891 (0.743)	3.345 (0.521)	-2.351	0.024*
Relevance	2.739 (0.704)	2.716 (0.629)	2.761 (0.787)	-0.212	0.833

Table 5: GERS results, including mean scores (μ) and rank (r) descending by the overall mean rating score (μ) from all participants, stranger group (SG) and peer group (PG)

Game Element	SG+PG μ (r)	SG μ (r)	PG μ (r)
VR Headset	3.545 (1)	3.591 (1)	3.455 (3)
Collaboration	3.523 (2)	3.545 (2)	3.500 (2)
Mission	3.477 (3)	3.409 (3)	3.545 (1)
Level	3.227 (4)	3.091 (7)	3.364 (5)
Puzzle	3.182 (5)	3.000 (10)	3.364 (6)
Role-Play	3.091 (6)	3.318 (5)	2.864 (8)
Unpredictable Event	3.091 (7)	2.773 (9)	3.409 (4)
Non-Linear Navigation	3.023 (8)	2.864 (10)	3.182 (7)
Avatar	3.023 (9)	3.364 (4)	2.682 (9)
Guide	2.727 (10)	3.227 (6)	2.227 (12)
Virtual Good	2.318 (11)	2.182 (13)	2.455 (10)
Haptic Feedback	2.295 (12)	2.227 (12)	2.364 (11)
Freedom to Fail	2.273 (14)	2.682 (11)	1.864 (16)
Storytelling	2.182 (13)	2.136 (14)	2.227 (13)
Cinematic Scene	1.841 (15)	1.818 (15)	1.864 (17)
Audio Effect	1.750 (16)	1.500 (16)	2.000 (14)
Animation	1.705 (17)	1.500 (17)	1.909 (15)

well-structured IVR activities can improve teamwork and problem-solving skills while promoting long-lasting collaboration skills and relationships.

6 Discussion

RQ1: How do gamification elements in an IVR learning environment influence intrinsic and extrinsic motivations during collaborative learning, and what are the differences when learning with a peer versus a stranger?

The integration of gamification elements within IVR was found to significantly increase team interaction and motivation to learn, regardless of the type of team. In particular, elements such as “collaboration” and “VR headsets” maintained consistent effectiveness in both PG and SG participants, demonstrating their usefulness to promote motivation in the IVR environment. This consistency suggests that these two game elements play an important role in promoting group collaboration and immersive learning, regardless of the relationships between team members.

In contrast, other game elements, such as the “puzzles” and “levels”, showed a variety of classifications depending on the type of team, which performed less effectively in participants in SG compared to participants in PG. The likely cause of these differences is the lack of prior collaboration experience between strangers, which could have affected their ability to work effectively on complex problems. Interestingly, the “role-playing” and “avatars” ranked higher in the SG participants, probably due to the anonymity provided by these game elements. The Social Identity De-Personalization Theory (SIDE) [47] suggested that the ‘role-play” game element allows strangers to reduce self-awareness, facilitating open self-expression, especially in unfamiliar social interactions. The study by [34] supported this concept, indicating that anonymity encourages bolder expressions and actions. This high ranking reflects the potential of the “role-play” game element to promote initial social interaction, reduce social inhibition, promote creativity and improve team collaboration. Therefore, the “role-play” game element should be considered when designing gamified learning activities or team building events that aim to promote communication and collaboration between strangers.

In addition, SG participants scored higher mean scores on the “guide” and “freedom to fail” game elements compared to PG participants. The lack of prior collaboration experience among strangers probably increased their need for clear guidance and structure. This indicates that clear guidelines provide direction, decrease uncertainty, and ease pressure in early collaborations [6]. “Freedom to fail” game element also promoted collaboration in the SG participants by offering a risk-free environment in which participants could experiment with different solutions without fear of immediate consequences. This setting encourages innovation, risk taking, and personal growth, which are critical to promoting learning within groups [21]. By integrating these elements, SG participants can reduce initial discomfort and promote long-term group cohesion and mutual growth. Future research could further examine how these game elements influence team dynamics in diverse cultural contexts and gender groups, and how they can be effectively implemented in IVR education.

The rankings of three game elements also stood out for PG participants. “Unpredictable event” game element was ranked higher in PG participants compared to SG participants, likely due to the existing trust among PG participants. The “unpredictable event” game element was perceived as opportunities to confront challenges together, helping to strengthen team cohesion and shared responsibility. The study by [12] also suggests that established relationships make peers more comfortable expressing emotions in unpredictable situations, leading to greater emotional resonance and support within the team.

Meanwhile, “nonlinear navigation” game element was also one of the high-rank game elements in the PG participants. Familiarity with each other’s behavior and decision-making processes likely made this game element more enjoyable, as it allowed for autonomous exploration and collaborative problem-solving. The “non-linear navigation” game element demands greater communication and collaboration, and the established relationship for peers facilitated this highly interactive environment. The final game element that was ranked higher in participants in PG than in SG was “storytelling” game element. Although not highly ranked overall, “storytelling” game element allowed peers to share experiences and emotions, deepening empathy and mutual understanding. This game element promoted collective identity by reinforcing shared narratives, which is important for long-term team cohesion.

In general, the discussion highlights how these game elements can significantly impact the dynamics and effectiveness of participants in SG and PG, in the aspects of promoting teamwork, emotional communication, and collective efficiency. This provides useful guidance in designing gamified tasks that specifically target participants in SG and PG.

RQ2: How do gamification elements in an IVR learning environment affect the overall user experience, particularly regarding the impact of social interaction on learning outcomes when collaborating with a peer versus a stranger?

The findings revealed that the participants in PG scored significantly higher in confidence and satisfaction compared to those in SG. This suggests that familiarity among team members increased their confidence and satisfaction with the game tasks, reflecting an increase in intrinsic motivation. A higher sense of competence and fluency was also observed in PG participants, likely due to the established and experienced collaborative history that reduced psychological barriers, allowing more effective engagement and enjoyment of the learning process.

Although no significant differences were found in the social presence module, PG participants slightly outperformed SG participants in all dimensions, suggesting that PG participants exhibited greater empathy and behavioral involvement. PG participants felt more comfortable expressing emotions and participating freely in group activities. In fact, the "weak link" theory [24] indicated that participants in SG may have more novelty and space for exploration, but exhibit lower levels of emotional expression and indirect interactions.

An interesting observation emerged in the positive and negative experience components, where participants in both groups displayed similar patterns. However, tiredness levels were slightly lower in participants in the PG, possibly due to established social contracts and habitual collaboration during the game. The most significant difference between the two groups was observed in the "returning to reality" component, where participants in PG scored significantly higher than in SG. This finding suggests that peers were more immersed in the gaming experience, making the transition back to reality more challenging. This deeper immersion indicates stronger emotional involvement during the game, which should be taken into account when designing games that require deep teamwork.

In general, these findings highlight the importance of considering the effect of relationships when designing an IVR learning-based game, as they significantly influence user experience, emotional engagement, and learning outcomes.

6.1 Limitations and Further Work

Several limitations were observed in this study. Individual variations and prior exposure to immersive, gamified learning settings may shape learners' preferences and experiences, even within the same group. For example, while one participant rated the experience highly, another on the same team gave a significantly lower rating, indicating that these differences can greatly affect perceived educational value. Moreover, a participant's unexpected fear of a virtual snake during mini-game 1, which led to their request for help, highlights the need to anticipate and manage emotional responses to specific stimuli. The study also did not explore how changes in the team, such as a member assuming a leadership role, might influence the nature and goals of collaborative learning. Future work should integrate both theoretical and empirical data to thoroughly explore how individual emotional responses and change of role in the team influence the effectiveness of immersive and gamified educational methods.

Future work aims to expand the target population beyond undergraduate and postgraduate students by including participants from various academic levels, ages, genders, and educational backgrounds. It also aims to address individual differences and game characteristics by focusing on learners with different personality traits. Future work also involves developing custom learning content adapted to different topics and difficulty levels, allowing a more comprehensive evaluation of the effectiveness of game elements in promoting team-based learning. Moreover, future work considers integrating objective measures like task completion times, interaction frequencies and types, and communication patterns to complement self-reported data and reinforce the findings.

Future work also aims to include a peer instruction method in the gamified learning environment of IVR, investigating whether taking on teacher or learner roles during collaboration affects learning outcomes and motivation of participants. This method would improve our understanding of how role differentiation affects educational outcomes and engagement in IVR environments. In addition, recent studies have mainly focused on motivational factors rather than directly measuring educational results. Although the findings show that integrating gamification in IVR settings can increase the engagement of learners, future work should consider using more comprehensive educational evaluations to determine whether such interventions contribute to long-lasting and significant learning improvements.

7 Conclusion

This study explored the impact of game elements within an avatar-based, multi-layered IVR learning environment on collaborative learning for the university students. By comparing the influence of these elements on students working alongside peers versus strangers, the work highlighted how gamification with proper design of game mechanics improves social interaction and motivation. Key findings revealed that while participants from both PG and SG benefited from IVR gamified tasks, their preferences for specific game elements varied. PG participants favored game elements such as "collaboration", "puzzle", and "unpredictable event", due to existing trust and familiarity. In contrast, SG participants preferred "role-play", "guide", and "freedom to fail" game elements, indicating the need for structure and anonymity in new social contexts. These results highlight the importance of considering team dynamics when designing collaborative learning activities in IVR settings. Game elements that build trust, creativity, and risk taking significantly improve team cohesion, especially among unfamiliar individuals. In addition, the findings present avenues for future research, particularly in inspecting the long-term impacts of gamification on learning. The adaptation of gamified activities to different types of relationships and individual personality traits can lead to more inclusive and effective IVR learning environments, promoting teamwork, creativity, and collaborative problem-solving skills. This study provides a suggestion for educators and practitioners to integrate game elements that adapt social familiarity and team dynamics. For example, open-ended puzzles can be used with peer-formed teams, while role-based guidance is beneficial for stranger-formed teams to promote engagement, team building, and collaboration. Conclusively, this study offers useful insights into the potential of gamification to improve educational experiences in IVR settings and provides practical design recommendations for more engaging collaborative learning tools.

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