Engagement Strategies in a Peer-quizzing Game: Investigating Student Interactions and Powergaming

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Abstract: Educational games are a popular means of engaging students in learning activities. However, students in game-based learning environments often engage in powergaming to reap undeserved rewards and spoil the experience of their peers. This may happen when the students pretend to engage in game activities or collude with other students, exploiting the game settings and rules to maximize their points. In this explorative study, we investigate powergaming in three settings of an asynchronous online multiplayer peer-quizzing game in a blended learning setting – a first-year programming class in a Canadian university. We designed three experimental settings with three versions of an education game which allowed different levels of powergaming. The between-subject study involved three experimental groups: Group 1 used a game version where they received weekly performance feedback and tips on how to improve their performance, Group 2 used a game version with access to an existing resource bank, allowing them to maximize the number if their activities in the game, and Group 3 served as a control group with no additional interventions. The research aimed to investigate 1) the association between the power gamers' activity, their grades and their preference to work alone or in a group, 2) the types of activities (type of quiz questions) most used by power gamers, and 3) which game setting was the most conducive to power gaming. The results show that better grades are not associated with higher activity levels in the game. Students who engaged in more diverse types of game activities had better learning outcomes The control Group 3 had the highest average grades. As we expected, Group 2 engaged in the highest number of activities, esp. in creating questions, a form of powergaming. The qualitative results showed that contrary to our assumption the powergamers in Group 2 was not harmful, because it created a rich set of resources in the game and fostered student engagement in the game.

Keywords: Serious Games, Game-based Learning, Peer-quizzing, Engagement

1. Introduction

Game-based learning (GBL) has emerged as a promising pedagogical approach that harnesses the engaging and motivating power of games to facilitate learning (Marques and Pombo, 2021; Riet, 2019). By incorporating game elements, mechanics, and principles into educational contexts, GBL aims to create immersive, interactive, and enjoyable learning experiences that promote active participation, problem-solving, and knowledge acquisition (Bösche and Kattner, 2011). The growing interest in GBL in blended learning is driven by the recognition that traditional, passive lecture-based learning practices often fail to capture and maintain learners' attention, resulting in poor retention rates (Calle et al., 2019; Soo and Lee, 2022).

In contrast, well-designed educational games have the potential to tap into learners' intrinsic motivations, reduce lapses in attention, and maximize knowledge retention and prevent learners from blanking out during exams (Calle et al., 2019; Iverson, 2019). The success of GBL depends on various factors, including the visual and audio impact of the game, the appropriate blend of challenges, rewards, learning content, and assessment units, and the overall narrative structure that binds these elements together (Stefan et al., 2022; Wang et al., 2016).

In this paper, we study the gameplay behaviour of students playing three versions of an online asynchronous peer-quizzing game in a blended learning environment during one academic term. The game developed in our lab is called ToQ (Towers of Questions) (Kiron et al., 2019; Kiron and Vassileva, 2018). The game offers three types of quiz questions: multiple-choice questions (MCQs), true/false questions, and short answer questions. Students can create quiz questions, answer questions created by their peers, and review the questions they have already solved. The game rewards are points that can be earned by creating quiz questions and answering them correctly.

We wanted to explore if variations of the game setup that could make it easier to power-game would lead to increase in powergaming. We also wanted to explore if there is any relationship between the preferred studying mode (alone or group) of students and their activities in the game, including their preferred question types. The rationale for exploring this relationship is constructing the three types of question (MCQ, T/F, and Short answer) demands distinct thinking processes. For instance, in a multiple-choice question, the student needs to create effective distractors. Students need to create T/F questions that are not easily apparent to their classmates. Short answer questions require more effort to evaluate the possible answers.

The participants were 1st year students in an Introduction to Programming course, who were randomly assigned to three groups each using a different version of the game. The first two groups, Groups 1 and 2, played versions of the game that included additional support: the version played by Group 1 included instructions and tips on creating good quiz questions and the version used by Group 2 provided a question bank from where students could choose and posting questions as their own. Group 3 played the game without additional supports.

The study has three primary objectives. The first objective is to explore which experimental group shows signs of hyperactivity or powergaming. The second objective is to analyse the relationship between the students' preference for learning (alone or in group), their in-game actions, and academic performance, with particular attention to the most active students who could be powergamers. The in-game actions include asking or answering questions and browsing the solved questions and the question bank (for Group 2). The third objective is to identify the most frequent categories of quiz questions (Multiple Choice Questions, True/False, and Short Answers) used by power gamers. Understanding the preferred question types will shed light on power gamers' learning strategies and preferences. By addressing these three objectives, this paper aims to contribute to the understanding of powergamers' behaviour, how effectively they learn and if they harm or benefit their peers in the context of a peer-quizzing game. The findings could inform the design of educational games.

2. Background

Game-based learning (GBL) has gained significant attention in recent years as an innovative pedagogical approach in higher education. By incorporating game elements and principles into educational contexts, GBL aims to create engaging, interactive, and motivating learning experiences for students (Guerrero-Quiñonez et al., 2023; Islam, 2017). The use of gamification techniques, such as challenges, rewards, competitions, and immediate feedback, can enhance learning effectiveness and promote active participation, collaboration, and problem-solving skills (Ceccarini and Prandi, 2022; Islam, 2017).

One of the key components of GBL is the use of rewards to motivate and reinforce desired behaviours and learning outcomes (Nipo et al., 2023; Perbawa and Rapiyanta, 2024). Rewards in educational games can take various forms, such as points, badges, leaderboards, virtual currencies, or unlockable content (Dong, 2023; Featherstone, 2022). However, the use of rewards in GBL is not without its potential drawbacks and negative consequences. An overemphasis on extrinsic rewards can undermine learners' intrinsic motivation, shifting their focus from the natural value of learning to the pursuit of external incentives (Kaldarova et al., 2023; Klit et al., 2020). This can lead to a superficial engagement with the educational content, where learners prioritize the acquisition of rewards over deep understanding and meaningful learning (Yu and Tsuei, 2022).

Another concern in GBL is the potential for students to exploit the game mechanics and reward systems in ways that subvert the intended learning objectives (Dong, 2023). Some learners may find ways to "game the system" by discovering loopholes, cheats, or strategies that allow them to earn rewards without genuinely engaging with the educational content. The exploitation of GBL by some students can have negative ripple effects on the learning experiences of their peers (Klit et al., 2020). When a significant portion of the learner population engages in exploitative behaviours, it can disrupt the collaborative and supportive learning environment that GBL aims to foster (Kaldarova et al., 2023). Other students may feel pressured to adopt similar strategies to keep up with their classmates, leading to a breakdown in the social dynamics and a loss of trust and cooperation within the learning community.

To mitigate these issues, educators must carefully design and implement GBL activities, striking a balance between intrinsic and extrinsic motivation (Fu and Yu, 2006). This can involve using a variety of reward types, such as social recognition and meaningful feedback, alongside tangible rewards (Caeiro-Rodriguez et al., 2021). Additionally, educators should establish clear guidelines and expectations for student behaviour, emphasizing the importance of academic integrity and genuine engagement with the learning material.

Game-based learning has the potential to revolutionize higher education by creating engaging and interactive learning experiences. The use of rewards can be a powerful motivational tool. Still, it is essential to consider the potential negative consequences of an overreliance on extrinsic rewards and the exploitation of the system by some students. By carefully designing GBL activities and fostering a culture of intrinsic motivation and academic integrity, educators can harness the benefits of game-based learning while minimizing its drawbacks, such as powergaming.

3. Experiment Design

This section provides an overview of our research methodology, including details on how we recruited the participants, designed the experiment, and collected the data. This study was granted approval by the behavioural ethics board of our university, identified as BEH ID-101. Students were recruited from a first-year programming language course. Participation in the study was voluntary, and as an incentive, students who actively participated in the game had the opportunity to earn up to five percent of their final grade as participation marks in the class. Students who decided not to be a part of the study had the five percent grade added to their final exam's weight.

After giving their informed consent, the students were directed to a pre-survey, which collected their information about their study preference. After removing those who opted out of the study or dropped the class, n=128 students participated in the study. The students were divided into three groups at random, with each group playing a different game version. The first group, Group1 (n=41), received feedback and suggestions from moderators. The second group (n=47) had access to a pre-existing question bank, and the third group, Group 3 (n=40), served as the control group, playing the game without support. The uneven number of students in the groups is a result of some students dropping out of the game or the course during the study.

The students were given pseudonyms to participate anonymously in a peer-quizzing game themed as a tower defence game. The game's theme revolves around students creating quiz questions (towers) based on the course material they are studying, answering the questions (attacking the towers) created by their peers and browsing the already answered questions (conquered towers). The game rewards are points that can be earned by creating quiz questions and by answering questions correctly. The students played the game alone and asynchronously using their computer's web browser. They logged in to the game using the credentials provided to them after signing up the consent form. There was no chat, or another communication channel provided for them in the game environment. The game interface featured segments tailored for the experimental groups. When students logged in to the game, they saw their version of the dashboard. For Group 1, weekly feedback was shown to the students including tips for creating good questions. A link to an existing question bank was shown only to Group 2. Group 3 was shown the game's interface without any extra support.

To gather comprehensive data for the study, we collected information from various sources. In addition to the pre- and post-study survey responses, we obtained gameplay data for each student. This data included the number of questions each student created and answered throughout the game. Furthermore, we collected a detailed log of all the events that occurred within the game. This log contained the specific questions students created, answered, and viewed, along with precise timestamps indicating when they signed in and out of the game.

4. Data Analysis and Results

The students' game performance, preferences for working alone or in a group, and class performance are presented in Tables 1 - 3. The activities performed by each experimental group in the game are summarized in Table 1. Group 2, with 47 students, had the highest levels of activity across all three metrics - questions created (45.31%), questions answered (33.38%), and questions browsed (39.35%). Group 1, with 41 students, had the lowest activity in answering (24.64%), and browsing (27.77%). Group 3, with 40 students, created fewer questions (26.42%) than the other two groups, but answered the highest number of questions (41.98%). This may suggest that group size alone does not determine activity levels, and there may be other factors influencing student engagement with the game, such as the different game supports provided to each group and the dynamics created within each group. Group 2 with the access to a question bank was the most active in creating new questions (which was easier, having access to a question bank) and engaged in browsing solved questions.

To determine if there are significant variations between groups, we need a breakdown of solo vs. group work preferences. Table 2 displays each group's preference for working individually or in a group. Interestingly, most students in Groups 2 and 3 preferred working alone (55.32% and 62.50%, respectively), while the students in Group 1 were evenly split between group and solo work preferences.

The average percentage grades for each group on assignments, lab tasks, and their final grade are presented in Table 3. Group 3 had the highest average scores across all three measures, with an 88% on assignments, 90% on labs, and an 81.46% final grade. The scores of Group 1 and Group 2 were similar, though Group 2 slightly outperformed Group 1 in the average final grade (75.38% vs 74.82%).

Table 1: Summary of game activities by experimental groups.

Group 1 (n=41)	Created	229	28.27%
	Answered	189	24.64%
	Browsed	1394	27.77%
Group 2 (n=47)	Created	367	45.31%
	Answered	256	33.38%
	Browsed	1976	39.35%
Group 3 (n=40)	Created	214	26.42%
	Answered	322	41.98%
	Browsed	1651	32.88%

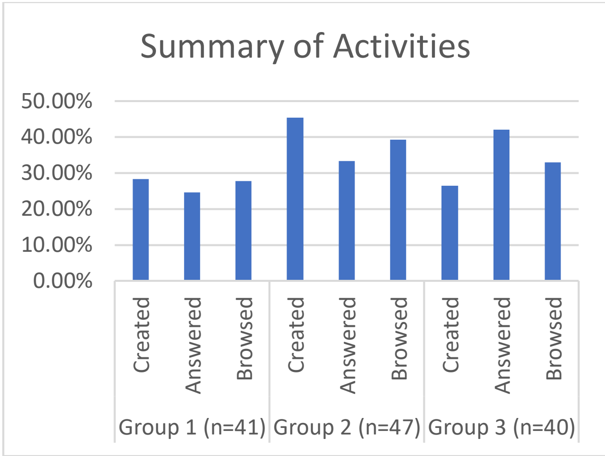
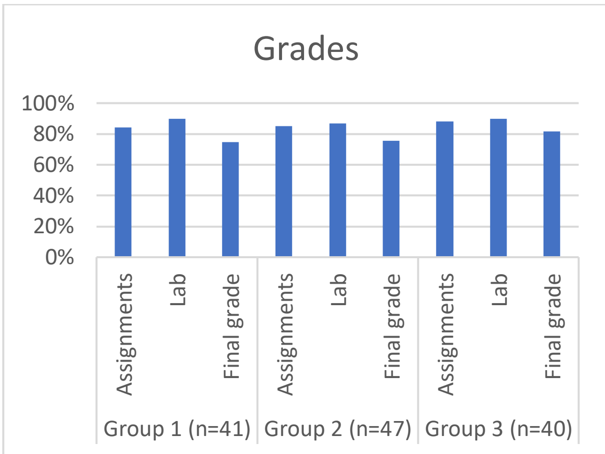


Table 2: Students' preference for working alone or in a group by experimental groups.

Group 1 (n=41)	Group	20	48.78%
	Alone	21	51.22%
Group 2 (n=47)	Group	21	44.68%
	Alone	26	55.32%
Group 3 (n=40)	Group	15	37.50%
	Alone	25	62.50%

Table 3: Average percentage of grades of students in experimental groups on assignments, lab tasks, and final grade.

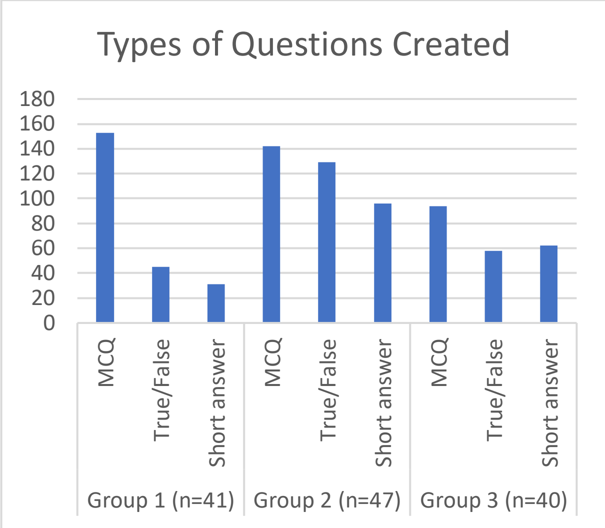
Group 1 (n=41)	Assignments	84%
	Lab	90%
	Final grade	74.82%
Group 2 (n=47)	Assignments	85%
	Lab	87%
	Final grade	75.38%
Group 3 (n=40)	Assignments	88%
	Lab	90%
	Final grade	81.46%



The type of questions asked by the students could impact game dynamics and engagement levels. Table 4 shows the breakdown of the types of questions - multiple choice, true/false, and short answer - used by each group in the game. Group 1 created the most multiple-choice questions (153), and much fewer true/false (45) and short answer (31) questions. Group 2 had a more even split between multiple choice (142), true/false (129) and short answer (96). Group 3 created multiple-choice the least (94) with a fairly even number of true/false (58) and short answer (62) questions. This provides insight into the question style preferences of each group. Group 1 favoured multiple choice, while Group 3 used it the least. Group 2 utilized all three question types more evenly.

Table 4: The types of questions created by each experimental group.

Group 1 (n=41)	MCQ	153
	True/False	45
	Short answer	31
Group 2 (n=47)	MCQ	142
	True/False	129
	Short answer	96
Group 3 (n=40)	MCQ	94
	True/False	58
	Short answer	62



The correlation coefficients for the different factors in each experimental group can be found in Table 5. We calculated the correlation coefficient using various factors including students' preferences for working alone or in a group, the number of questions asked, answered, and browsed, and the grades obtained (assignment grades, coding lab grades, and their final grade).

Table 5: The correlation coefficients for each of the experimental groups.

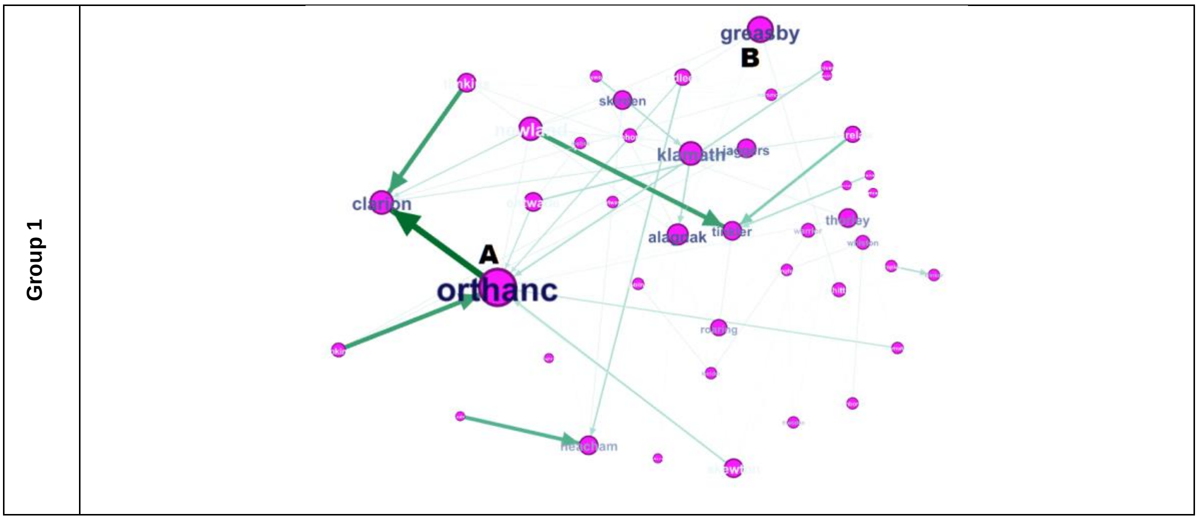
		Preference Group/Alone	Asked	Answered	Browsed	#Assignments	#Codelab	#Final Grade
Group 1	Group/Alone	1.000						
	Asked	0.070	1.000					
	Answered	0.261	0.298	1.000				
	Browsed	0.228	0.443	0.747	1.000			
	#Assignments	-0.052	0.243	0.240	0.310	1.000		
	#Codelab	0.051	0.143	0.154	0.179	0.555	1.000	
	#Final Grade	-0.138	0.020	0.110	0.220	0.786	0.579	1.000
		Preference Group/Alone	**Asked**	**Answered**	**Browsed**	**#Assignments**	**#Codelab**	**#Final Grade**
Group 2	*Group/Alone*	1.000						
	Asked	-0.103	1.000					
	Answered	-0.179	0.577	1.000				
	Browsed	-0.249	0.733	0.897	1.000			
	#Assignments	-0.110	0.246	0.205	0.291	1.000		
	#Codelab	-0.085	0.273	0.189	0.281	0.776	1.000	
	#Final Grade	-0.227	0.096	0.234	0.265	0.855	0.701	1.000

		Preference Group/Alone	Asked	Answered	Browsed	#Assignments	#Codelab	#Final Grade
Group 3	*Group/Alone*	1.000						
	Asked	0.044	1.000					
	Answered	-0.011	0.757	1.000				
	Browsed	0.039	0.826	0.900	1.000			
	#Assignments	-0.219	0.280	0.182	0.254	1.000		
	#Codelab	-0.212	0.242	0.189	0.240	0.808	1.000	
	#Final Grade	-0.368	0.178	0.160	0.237	0.852	0.820	1.000

Across all three groups, strong positive correlations can be seen between the game activity metrics, especially questions browsed and answered. The likelihood of questions being answered increases with higher levels of browsing questions. Assignment grades, lab scores, and final grades also tend to be strongly correlated, which is logical as assignments and labs are components of the final grade. Interestingly, game activities have only weak to moderate positive correlations (varying between and 0.020 to 0.291) with assignment, lab and final grades performance. The highest correlations can be found in Group 2, with correlations of 0.291, 0.281 and 0.265 between questions browsed and assignments, labs, and final grades, respectively. It is interesting to note that unlike in Group 1 and 2, in Group 3 the correlations between the grades and the number of questions asked are higher than those for questions browsed. This could suggest that creating new questions without any support has a stronger effect on learning performance. Yet, the differences are small. Overall, it seems that in-game activities do not readily translate to higher academic performance in assignments and exams.

In Group 1, there is a negative correlation (-0.138) between students' preference for working alone or in a group and their final grade, indicating that those who prefer group work tend to have slightly lower grades. The preference for working alone or in a group in Group 2 and Group 3 is negatively correlated with variables such as answered, browsed, and final grade. This indicates that students who prefer group work tend to have lower engagement in these activities and possibly lower final grades.

Figure 1 shows the social network of interactions between students in each experimental group. The directed edges represent interactions (solving a question created by the other student). The size of each node represents it centrality (i.e. the number of interactions with different peers).



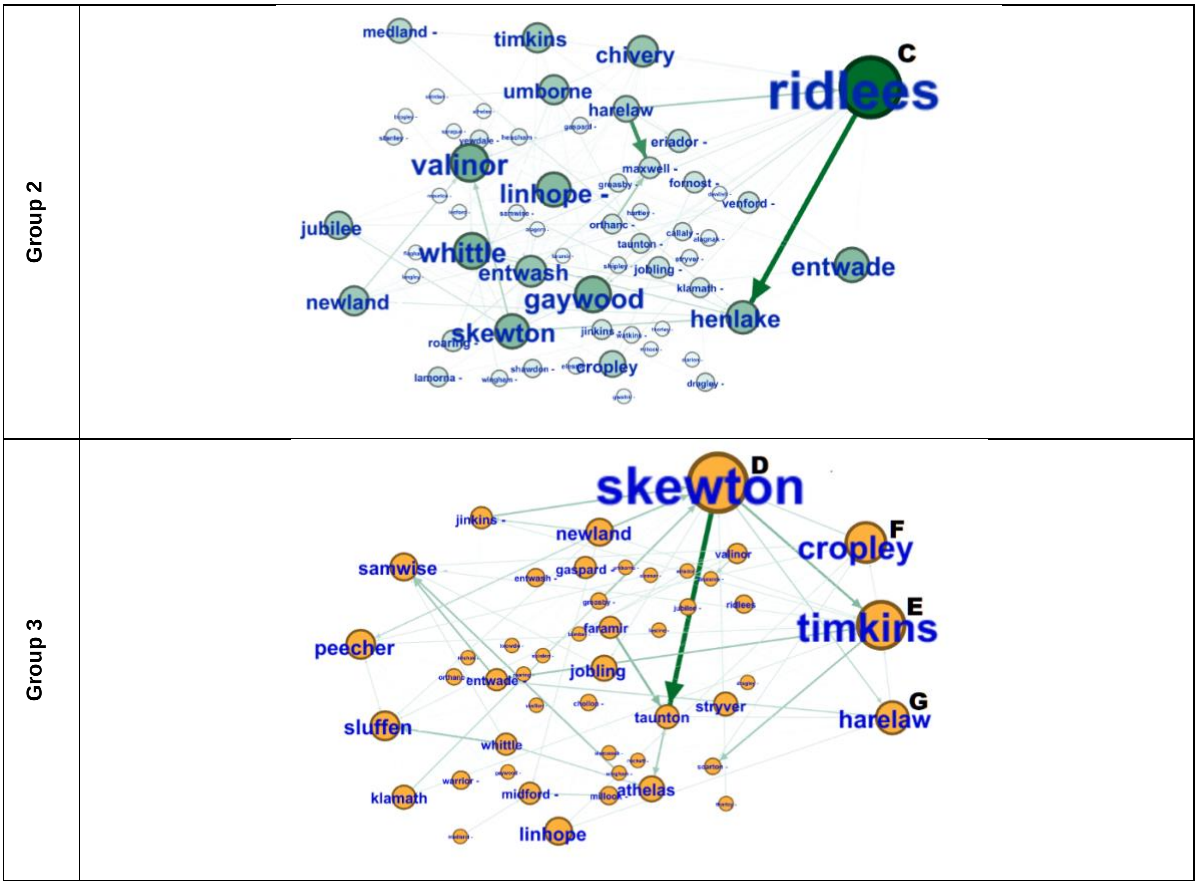


Figure 1: Network graph of the experimental groups. The nodes are the students, and the edges show their interactions with other students. The size of the node corresponds to the number of questions created.

When comparing the activity of students in terms of question creation, which could be a sign of powergaming, Group 1 (Density: 0.043) has two visibly large nodes (A and B), Group 2 (Density: 0.045) has one large Node (C), and Group 3 (Density: 0.048) has three large nodes (D, E, and F). The thickness of an edge represents repeated interactions between two nodes that may potentially signify a collusion (another forum of gaming). We observe that in Group 1 there are 5 to 6 pairs of students who engage in repeated interactions, while in Group 2 and 3 there are only 2-3 such pairs.

5. Discussion and Limitations of the Study

The findings from this exploratory study offer several points for discussion regarding student behaviour and performance in educational games or online learning platforms. One key area of interest is the relationship between activity levels and grades. Although one might assume that increased engagement leads to higher scores, these findings indicate a more complex relationship. The activity levels of Group 2 were the highest across two out of the three metrics in Table 1, and they also had the second densest network of student interactions in Figure 1. However, this group had average grades that were neither high nor low compared to the other two groups.

In contrast, Group 3 had the lowest activity in two out of the three metrices according to Table 1, and highest activity levels and the most connected network, and they obtained the highest average grades. This brings up uncertainties regarding the form and level of engagement that promotes optimal learning. It is possible that Group 3's approach of selective, focused interactions and a preference for solo work allowed for deeper processing of the material, leading to better outcomes. The results of our study are consistent with Tejada-Simon's research (Tejada-Simon, 2024). They reported there was no statistically significant connection between student engagement with the games and their course grades.

Another notable point is the varying use of question types across groups. Group 1's heavy dependence on multiple-choice questions and their avoidance of short answer questions, coupled with their lower average grade, indicates that the choice of question format could affect the learning process. Short-answer questions might encourage deeper understanding compared to multiple-choice questions. Utilizing a variety of question types may have helped Group 3 perform better. Another factor is whether someone likes to work alone or in a group. Group 3, which had significantly more students who preferred working alone than students who preferred working groups, performed better than the other two groups where the student preferences were more balanced. However, the correlations in Table 5 don't show a clear, consistent relationship between group work preference and performance metrics.

Finally, we noticed some evidence of powergaming by a few students in all groups. However, we did not observe any negative effects of powergaming on the other students. On the contrary, it seems that the contributions by the powergamers were beneficial to other gamers. First, these students created a positive example through their gameplay behaviour. Even in Group 2, where they had a source of questions they could use, they did not copy directly questions from the database, but tried to improve them. By creating many questions, they made sure that there were always questions available to other students that they could answer. Second, powergamers can generate imperfect questions that may stimulate other players to adapt and improve them. This involvement can result in deeper exploration of subjects, exposure to diverse viewpoints, and a more enriching learning experience for all. Third, powergamers may introduce topics not taught in the class, adding unique questions to the question bank of the game. The question bank can become a supplementary learning resource. Finally, the presence of powergamers raises the overall game interaction and energy in the class, fostering a more dynamic and stimulating learning environment that benefits everyone.

It's important to consider the limitations of the study. The sample sizes of each group are relatively small, with 40-47 students each. Larger samples would provide greater confidence in the patterns observed. The specific design of the educational game or platform could also skew behaviours and outcomes. Despite these limitations, this experiment offers valuable insights into how different interaction patterns and preferences among students relate to learning outcomes. It challenges assumptions that more activity and interaction are always better and highlights the need to consider the type and quality of engagement. Future research will explore these dynamics in more depth, with larger samples and a wider range of academic contexts.

6. Conclusion

The study explores the complex connections among student behaviours, preferences, and performance in an educational game. A comparison of the engagement and performance of three groups of students under different game conditions, considering activity levels, question type usage, solo/group work preferences, and interaction patterns, uncovers several important findings. Higher activity levels do not necessarily translate to better grades. Although Group 2 had the highest levels of creating, answering, and browsing quiz questions, their average grades were only moderate. Meanwhile, Group 3 had lower activity but the highest grades. This suggests that the quality and type of engagement may be more important than sheer quantity.

The type of questions created by students may influence learning outcomes. The lowest average grades were observed in Group 1, which heavily utilized MCQs and avoided true/false and short answer questions. In contrast, Group 3's more balanced use of all question types aligned with their higher performance. This indicates that a mix of question types, including those that require articulating understanding, may be beneficial. The highest preference for solo work was observed in Group 3, which had the highest average grades. Correlations between group work preference and performance metrics were inconsistent across groups. This suggests that while these preferences shape interaction patterns, they don't necessarily dictate outcomes.

Student interaction patterns, as visualized in the network graphs, show some alignment with activity levels and grades. Group 2 performed well in activity levels and network density but had average grades. Despite having the lowest activity compared to Group 2, Group 3 achieved the most connected network, and higher average grades. Within groups, browsing and answering more questions correlated with better assignment and lab scores, which in turn correlated with higher final grades. Active engagement with course content, such as exploring and attempting questions, could enhance individual learning. Furthermore, the bigger nodes belong to the most active students who asked the most questions. Despite their tendency to be overactive, which could be considered as powergaming, they may have played a beneficial role in the game.

Future research could build on these findings by exploring similar questions with larger, more diverse samples and across different academic subjects and platforms. Qualitative data, such as quality analysis of the questions created (using experts or trained large language models), student interviews and content analysis of the interactions (attempted answers to questions, time to first correct answer, etc.), could provide deeper insight into the factors driving these patterns. This study emphasizes the importance of carefully designing and evaluating these platforms, considering activity levels, question types, interaction patterns, and individual preferences. Furthermore, while powergamers are usually seen as troublemakers in game-environments, our findings suggest that may be beneficial depending on the type of games. While their overactivity might be a concern for us, the overactive users were the ones responsible for providing questions for the other students to answer.

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