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Who wants to be a millionaire? A game-based approach to enhancing engagement and teamwork in immunology education

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Undergraduate Pharmacy students at Newcastle University reported difficulties with immunology topics, prompting the development of supportive seminar sessions. To determine the optimal teaching strategy, an experimental design was implemented over four academic years (2018–2022). In 2018–2020, half of the cohort participated in immunology seminars structured around open-ended group discussions, while the other half engaged in a competitive, team-based adaptation of *Who Wants to Be a Millionaire?*. The hypothesis was that the interactive, competitive nature of the game would enhance knowledge retention, student engagement and stimulation to teamwork. Students completed a pre-test (12 MCQs) before the main seminar activity and a post-test (six repeated and six new MCQs) to assess knowledge gain. A feedback form measured student perceptions of engagement and teamwork. In 2020–2022, due to the transition to online teaching, a mixed approach was adopted: all students participated in open-ended group discussions, but the MCQ pre-test and post-test assessments were gamified with a leaderboard. Results showed a statistically significant improvement in pre- to post-test scores across all formats, indicating that both game-based and traditional seminar approaches effectively supported knowledge retention. However, student feedback highlighted greater engagement and a stronger appreciation for teamwork in the game-based format. These findings suggest that game-based learning can enhance student motivation while maintaining learning outcomes achievements, supporting its integration into STEM curricula to promote active participation and teamwork skills.

KEYWORDS

gamification, immunology, teamwork, engagement, active-learning

1 Introduction

Undergraduate Pharmacy students often encounter difficulties when engaging with biology-related topics, such as immunology (Dirks-Naylor et al., 2019). These challenges stem from the abstract nature of immunological concepts, the complex interplay of cellular and molecular mechanisms, and the heavy reliance on memorization. As a result, students may struggle with knowledge retention, which can impact their overall performance (Siani et al., 2023).

To address these challenges, active learning strategies have gained traction in higher education as a means to enhance student engagement and facilitate deeper understanding (Freeman et al., 2014). Research in educational pedagogy suggests that student-centered approaches, such as collaborative learning and game-based activities, can significantly improve knowledge retention, engagement and motivation (Hamari et al., 2014). Traditional seminar-based learning typically involves small groups working together to answer open-ended questions, encouraging discussion and peer-to-peer learning (Balwant and Doon, 2021). While effective, this method may not capture the attention of all learners, potentially resulting in lack of teamwork and engagement with the seminar session and ultimately in lack of knowledge retention. Therefore, introducing more dynamic, interactive approaches is beneficial to stimulate students' learning and skills development (Aburahma and Mohamed, 2015).

Gamification, the application of game-design elements in educational contexts, has been recognized as one of these powerful tools to foster student engagement, promote teamwork, and reinforce learning (Deterding et al., 2011). Competitive educational games, such as quiz-based challenges, leverage motivation through competition and immediate feedback, potentially enhancing cognitive processing and long-term knowledge retention (Plump and LaRosa, 2017). Research has shown that game-based learning can increase student engagement by creating an enjoyable and immersive learning environment (Subhash and Cudney, 2018). Furthermore, games encourage teamwork and collaborative problem-solving, all essential skills for Pharmacy students who will work in interdisciplinary healthcare settings (Aburahma and Mohamed, 2015). When students participate in game-based learning, they are more likely to remain actively involved, develop a positive attitude toward learning, and retain information more effectively (van Roy and Zaman, 2018). Additionally, the inclusion of a structured competition can enhance motivation and persistence, leading to deeper cognitive engagement with the material (Buckley and Doyle, 2014). While gamification has been successfully applied in various educational contexts, its role in undergraduate immunology education within pharmacy programs remains underexplored.

This study contributes to the growing body of literature on gamification in STEM education by evaluating its effectiveness in an undergraduate immunology seminar setting, specifically within pharmacy education. In particular, this study explores how a competitive, game-based approach compares to traditional seminar discussions in supporting immunology learning for pharmacy students. Seminar sessions of immunology were designed in response to Stage 1 undergraduate pharmacy students at Newcastle University reporting difficulty with immunology topics. To assess the optimal teaching strategy to enhance students' knowledge retention, an experimental design was adopted for the academic years 2018–19 and 2019–20. Half the cohort experienced standard seminars requiring students to work in groups to answer open questions on the topic, whilst the other half of the cohort experienced a seminar adopting elements of the game "Who Wants to Be a Millionaire". Students played competitively in small teams. To compare within the standard seminar and game-based sessions, a feedback form including five 5-point Likert scale questions was distributed requiring students to rate different components of the sessions, including the level of engagement, stimulation to learn and teamwork.

By analyzing pre- and post-test knowledge performance and student feedback, this educational activity aims to investigate whether incorporating a game-based learning approach into an immunology seminar enhances student engagement, teamwork and knowledge retention compared to traditional group discussions. This approach seeks to provide insights into the effectiveness of gamification in Immunology education and its potential applications in curriculum design.

2 Methods

2.1 Format of the seminar sessions from 2018 to 2022

For the academic year 2018–19, eleven open questions were designed to test student knowledge and used for the standard seminar activity. Three sets of 15 multiple-choice questions (MCQs) were designed and used for the game-seminar activity. Prior to the described seminar activity, students undertook a pre-test of 12 MCQs to assess their knowledge, followed by a post-test, using six of the same pre-test MCQs and six new MCQs, to capture knowledge attainment.

For the academic year 2019–20, the design of the sessions was optimized to reflect students' feedback from the 2018–19 sessions and to accommodate timetable changes. The number of open questions in the standard seminar activity was reduced to nine, while two sets of 15 MCQs were used for the game-seminar activity. The pre-test and post-test of knowledge remained unchanged.

Results from the two academic years were compared within and between groups and a *t*-test was used to assess statistical differences.

Considering the results obtained in 2018–20 which indicated that both types of seminar activity enhanced students' knowledge retention, and due to teaching moving online because of the COVID-19 restrictions, a mixed approach was implemented in the academic year 2020–21. The seminar was conducted synchronously online via Zoom. Seven open questions were used for small-group discussions within breakout rooms as the main seminar activity. Students undertook a pre-test of knowledge consisting of six MCQs and a post-test of knowledge consisting of six different MCQs on similar topics. To maintain a competitive component in the session without the full game, the pre-test and post-test were structured as an individual quiz competition with a leaderboard.

In the academic year 2021–22, the seminar activity was conducted on campus using the same format as in 2020–21. Pre-test and post-test results from the two academic years were compared within groups and a *t*-test was used to assess statistical differences.

The format of the seminar sessions for all four academic years included:

- Pre-test of knowledge
- Main seminar activity (open questions or game activity)
- Post-test of knowledge
- Feedback form completion and collection

Stage 1 Pharmacy students were pre-assigned to one of four repeats of the scheduled seminar session as part of their regular timetable. To allocate groups for the study, two of the four sessions were randomly selected to experience the game-based seminar session, while the remaining two experienced the standard seminar. Random selection was performed using a random number generator, ensuring an unbiased allocation of conditions.

2.2 Content of the seminar sessions in relation to the immunology learning framework

The open questions used in the standard seminar sessions were grouped into three main areas: differences and functions of innate and adaptive immunity, structure and function of antibodies and mechanisms of immune responses. The MCQs used in the pre-test, post-test, and game activity, also covered these same three areas.

All the questions (MCQs and open questions) assessed key concepts within the "Systems" and "Structure and Functions" domains of the Immunology learning framework (Pandey et al., 2023; CourseSource, 2023). All seminars were conducted in small groups to foster teamwork skills and support the development of the key competency "Communicate and collaborate with others" within the framework (Pandey et al., 2024).

2.3 Set of rules created for the game activity "who wants to be millionaire"?

The "Who Wants to Be a Millionaire?" activity was modeled on the popular television quiz show format. In the original game, contestants answer individually a series of multiple-choice questions that increase in difficulty, with each correct answer progressing them toward a final prize. Participants may use up to three lifelines, such as 50:50 (Removing two of the four possible answers) ask the audience (The audience answers the quiz and the results are showed to the participant to inform their decision), or phone a friend (calling a friend by telephone to ask for their help with the quiz) to assist with difficult questions.

To adapt the game "Who Wants to Be Millionaire" from an individual to a team-based activity, a modified set of rules was developed. The game was created using a template available from the "SuperTeacherTools" website (http://www.superteachertools.us/millionaire) which allowed for the projection of game questions on the screen. Students were divided into three teams, while the lecturer acted as the game facilitator (Superteachertools, 2024).

Each round of the game consisted of a set of 15 MCQs, further divided into five rounds of questions on similar topics for the three participating teams. Teams took turns answering projected questions as shown below, with discussion encouraged before submitting each answer. Each team answered one question per round, and each round was worth the corresponding monetary value:

Round 1: questions 1–3: £50,000
Round 2: questions 4–6: £100,000
Round 3: questions 7–9: £200,000
Round 4: questions 10–12: £500,000
Round 5: questions 13–15: £1,000.000

A correct answer awarded the team the specified monetary value. To prevent disengagement from the session, an incorrect answer did not eliminate the team but resulted in a deduction of the question's value. For example, a team that answered correctly in Rounds 1 and 2 but incorrectly in Round 3 would have their total calculated as: 50,000£ + 100,000£ − 200,000£" = −50,000£. A whiteboard was used to update each team's earning after every round.

To introduce a strategic element, a team that answered incorrectly had to select one of the other two teams to attempt the question. If the selected team answered correctly, they received a bonus worth 50% of the question's value (e.g., in Round 3, this would be £100,000).

The winning team was the one with the highest total earnings at the end of the game.

In every round, each team was allowed to use only one of the three standard game lifelines: 50/50, Ask the Audience and Call a Friend. Lifelines introduced another layer of strategy: using a lifeline early allowed teams to choose one from all three options. Delaying its use to later could help on higher-value questions but may result in less available options to choose from. The "50/50" and the "Ask the Public" lifelines were managed directly on the online platform. The "Call a Friend" lifeline was adapted to "Go Online". Allowing one team 30 s to research the correct answer.

2.4 Feedback from the seminar activity

A feedback form was distributed to students, containing five 5-point Likert scale questions to evaluate various components of the session. These included: engagement, informativeness, knowledge reinforcement, stimulation to learn, and teamwork.

All feedback was collected anonymously. Descriptive statistics were used to analyze Likert-scale responses, and comparisons between different seminar formats were conducted to assess student preferences and engagement. The difference in engagement and teamwork between the game seminar session (2018–2020) and the standard seminar (2018–2020), mixed approach (2020–21, 2021–22) were further analyzed using the Mann-Whitney *U* test.

2.5 Ethical considerations

Students answered the pre-test, post-test and feedback form anonymously. Ethical approval was obtained from the University Ethics Committee (Ref: 14160/2018), and verbal consent was obtained from students to use the collected anonymous data for further analysis.

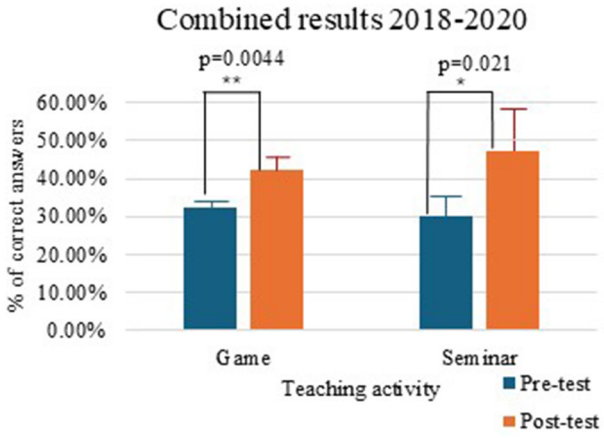

FIGURE 1
Student performance in pre- and post-tests for game and standard seminar formats (2018–2020). Mean percentage of correct answers in the pre-test (blue) and post-test (orange) for students participating in either a game-based seminar -"Who Wants to Be a Millionaire"- or a standard seminar with open-ended group discussions (Total number of students in 2018-19 cohort $N = 90$. In 2019–20 $N = 130$). A statistically significant improvement in student scores was observed for both teaching approaches ($p = 0.0044$ for the game-based seminar; $p = 0.021$ for the standard seminar), as determined by a paired t-test. Error bars represent the standard error of the mean (SEM). Asterisks indicate statistical significance (* indicate $p < 0.05$, ** indicate $p < 0.01$).

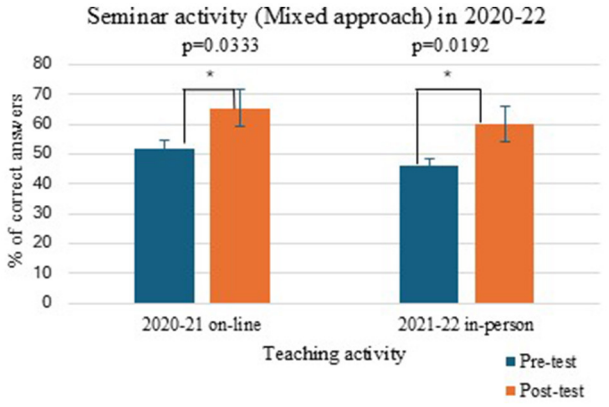

FIGURE 2
Student performance in pre- and post-tests for online and in-person seminar formats (2020–2022). Mean percentage of correct answers in the pre-test (blue) and post-test (orange) for students participating in synchronous online seminars (2020–2021, $N = 145$) or in-person seminars (2021–2022, $N = 170$). A statistically significant improvement in student scores was observed for both formats ($p = 0.0333$ for online; $p = 0.0192$ for in-person), as determined by a paired t-test. Error bars represent the standard error of the mean (SEM). Asterisks indicate statistical significance (* indicate $p < 0.05$).

3 Results

3.1 Both the game and the standard seminar enhance knowledge retention

In the academic years 2018–19 and 2019–20, half of the Stage 1 Pharmacy students participated in an immunology seminar using open-ended questions in small groups, designed to reinforce content from three previous lectures. The other half engaged in a game-based seminar modeled after "Who wants to Be Millionaire?", played in small teams. All students completed a pre-test (12 MCQs) before the main seminar activity and a post-test after the activity to assess knowledge gain.

Figure 1 illustrates the comparison of pre-test and post-test scores for both seminar types in 2018–20. A statistically significant improvement in post-test, was observed in both cases (p-values shown in Figure 1), confirming that both traditional group discussions and game-based learning effectively enhance knowledge retention in immunology of Stage 1 Pharmacy students.

3.2 A mixed approach also improves knowledge retention

In response to the COVID-19 pandemic and prior findings that both seminar formats enhanced knowledge retention, a mixed approach was introduced in 2020–21. All students participated in the standard seminar (open-ended questions in small groups), but the pre-test and post-test were redesigned as an individual quiz competition with a leaderboard to maintain a competitive element. Due to online teaching constraints, the quizzes were limited to six MCQs in each test. As shown in Figure 2, students demonstrated significant improvements in post-test results (p values shown in Figure 2), confirming that the mixed approach effectively enhanced students' knowledge retention. In 2021–22 when teaching returned in-person, the same seminar format used in 2020–21 was maintained. Once again, significant improvements were observed in post-test scores (Figure 2), demonstrating that the mixed approach was effective to enhance students' knowledge retention, regardless of whether sessions were delivered synchronously online or in-person.

3.3 Feedback trend across all the years highlight the game as the most engaging and teamwork stimulating activity

At the end of each seminar, students completed a feedback form with five 5-point Likert scale questions evaluating different aspects of the session, including engagement, usefulness for knowledge reinforcement, informativeness, stimulation to learn and teamwork. As shown in Figure 3, while both the traditional and game-based seminars were rated similarly for informativeness and knowledge reinforcement, students who participated in the game-based seminars reported higher levels of engagement, stimulation to learn and teamwork. Mann–Whitney U tests confirmed that both engagement and teamwork ratings were significantly higher in the game-based seminars (2018–20) compared to the standard seminar of the same period (engagement: U = 1,897; teamwork: U = 2,232. p-values

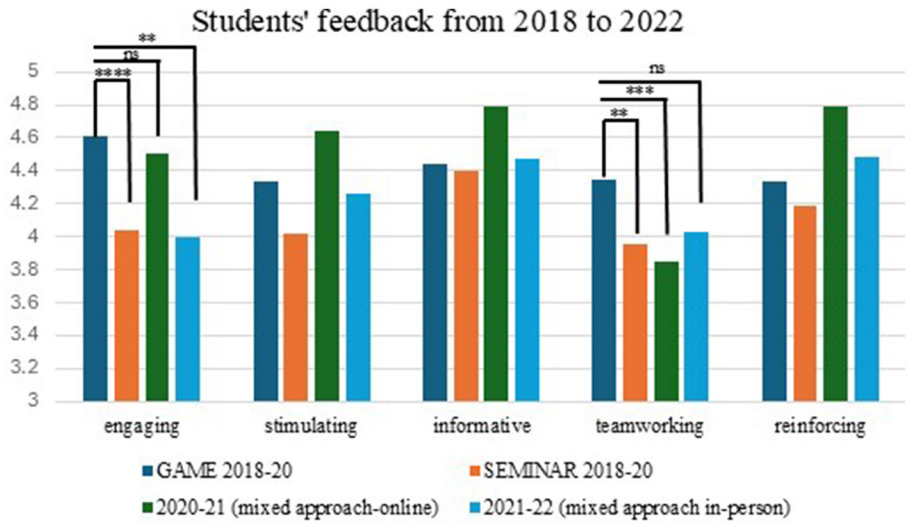

FIGURE 3
Student feedback on different teaching approaches from 2018–2022. Student perceptions of engagement, stimulation, informativeness, teamwork, and reinforcement were assessed using a Likert scale (1–5, where 1 = strongly disagree and 5 = strongly agree). Feedback was collected across four different teaching conditions: game (2018–20), seminar (2018–20), an online mixed approach (2020–21), and an in-person mixed approach (2021–22). In comparison to the seminar (2018–20), the game-based seminar received higher ratings for engagement, stimulating to learn and teamwork, while both methods were rated similarly in terms of informativeness, reinforcement. In 2020–21, ratings for engagement, stimulation, informativeness, and reinforcement remained high. The game consistently received the highest ratings for engagement and teamwork, while informativeness and reinforcement ratings remained similar across all approaches. Data are presented as mean scores. Engagement and teamwork students' ratings were further analyzed using a Mann-Whitney *U* test to assess statistical significance. Engagement ratings for game (2018–20) were significantly higher than those for seminar (2018–20) ($p < 0.00001$) and for in-person mixed approach (2021-22) ($p = 0.00122$). No statistical significance (NS) was found in comparing game (2018–20) to online mixed approach (2020-21) ($p = 0.43251$). Teamwork ratings for game (2018–20) were significantly higher than those for seminar (2018–20) ($p = 0.00964$) and for online mixed approach (2020–21) ($p = 0.00064$). (NS) was found when game (2018–20) was compared with in-person mixed approach (2021–22) ($p = 0.16853$). Asterisks indicate statistical significance (* indicate $p < 0.05$, ** indicate $p < 0.01$).

shown in Figure 3). These results support the interpretation that the game-based format enhanced both participation and collaboration.

The same five questions Likert scale feedback was used in 2020–21 and 2021–22 to evaluate students' perceptions of the seminar activity used in these two academic years.

As shown in Figure 3, in 2020–21, when teaching was online via Zoom, students rated the session's informativeness, knowledge reinforcement, stimulating to learn and engagement at levels similar to or higher than those seen in 2018–20 game-based seminars. However, teamworking scores were significantly lower than those of the 2018–20 game-based seminar (U = 2,122, *p* value shown in Figure 3), aligning more closely with those from the standard seminar used in the same period, suggesting that the online format may have limited opportunities for collaborative learning.

In 2021–22, with the return to in-person teaching, students again rated the session as stimulating, informative and reinforcing their knowledge at levels comparable to the 2018–20 game-based or standard seminars. Teamworking scores improved relative to 2020–21 but the mean (4.03) remained closer to that of the standard seminar (3.95) than to the game-based seminar (4.35). Although the game activity yielded a higher average teamwork score and a greater proportion of high ratings (91.6% of students rating 4 or 5 vs. 78.3% in 2021–22), this difference was not statistically significant (U = 2,256, *p* value shown in Figure 3).

In contrast, engagement ratings in 2021–22 were significantly lower than those from the game-based seminar (U = 1,688, *p* value shown in Figure 3), and aligned more closely with those of the standard seminar used in 2018–20. This suggests that students found the immunology session most engaging when delivered through the interactive game format.

However, in 2020–21 (an academic year where all lectures were pre-recorded due to the COVID-19 pandemic), engagement ratings were higher, suggesting that students particularly valued the few live interactive sessions during this year, regardless of format.

4 Discussion

The data collected over the years showed that a game-based activity inspired by the popular TV show "Who Wants to Be a Millionaire?", a standard seminar based on open-ended questions, and a mixed approach based on open-ended questions but including a competitive individual quiz competition, can all be used to augment student knowledge retention in a similar manner. Students showed a statistically significant improvement between pre-test and post-test scores in all circumstances (Figures 1 and 2). Our results align with published literature suggesting that game-based learning does not necessarily enhance students' knowledge retention more than other types of seminar activities (Domínguez et al., 2013; Rondon et al., 2013). This finding also supports previous research indicating that engagement in

active learning—whether through games or traditional interactive methods—contributes to knowledge acquisition at comparable levels (Freeman et al., 2014). Thus, our work demonstrates that Stage 1 Pharmacy-students participating in a game-based or a standard seminar in immunology will achieve the same learning outcomes, which are aligned with the key concepts of the immunology learning framework (Pandey et al., 2023; CourseSource, 2023).

Collected student feedback in the 2018–20 period, indicated that the game activity was perceived as significantly more engaging, and teamwork-stimulating compared to students attending standard seminar sessions with open questions (Figure 3). Engagement in teaching sessions is pivotal to student learning and knowledge retention. Research suggests that active participation in engaging activities leads to deeper understanding, better critical thinking skills, and increased motivation to learn (Michael, 2006). Game-based learning (GBL) in particular, has been shown to enhance engagement by fostering competition, enjoyment, and a sense of achievement, which can positively influence learning outcomes (Hamari et al., 2016). Designing sessions that maximize engagement, such as a game-based seminar, is therefore a key consideration for educators aiming to improve student learning experiences. Our findings align with those reported by a study published in *Computers*, which demonstrated that digital GBL significantly enhances student engagement and motivation compared to traditional online learning activities (Nadeem et al., 2023).

Teamwork is an essential skill in health sciences education, particularly for Pharmacists, who are frequently required to collaborate with other healthcare providers. Therefore, introducing game-based seminars into the Pharmacy-curriculum may support the development of such skills, as demonstrated in GBL approaches used in immunology and other scientific subjects (Lam et al., 2019; Frenzel et al., 2020; Barber, 2020). Moreover, "communicate and collaborate with others" is recognized as a key competency within the immunology learning framework, further justifying the use of game-based seminars in STEM education to enhance both subject-specific knowledge and professional skills (Pandey et al., 2024). Similar findings in other disciplines suggest that incorporating team-based learning strategies improves students' confidence and ability to work collaboratively in real-world settings (Thompson et al., 2007).

Additionally, incorporating a competitive element into a standard seminar, as tested in the mixed approach in 2021–22, did not substantially increase students' ratings for engagement or teamwork (Figure 3). This suggests that the game-format itself was necessary to attain a high level of engagement and to effectively stimulate teamwork. This is consistent with previous studies on the impact of gamification on motivation and student interaction (Deterding et al., 2011). Introducing competitive elements into educational settings without integrating them into a comprehensive game-based framework or into a cooperative environment may reduce engagement and performance (Bluestone, 2024).

Although the difference in teamwork ratings between the game-based seminar and the 2021–22 seminar was not statistically significant, this may reflect cohort-related variation or curricular changes over time. In particular, by 2021–22, Stage 1 pharmacy students had greater exposure to team-based learning activities, potentially raising baseline teamwork scores independently of activity format.

In 2020–21 when teaching was delivered online due to COVID-19 restrictions, students rated engagement and other feedback components highly, except for teamwork (Figure 3). However, in 2021–22, as in-person teaching resumed, engagement ratings returned to levels comparable to the 2018–20 standard seminar sessions (Figure 3). This pattern suggests that the elevated engagement scores in 2020–21 may have reflected students' greater appreciation for synchronous interaction during a predominantly asynchronous period.

This interpretation aligns with previous research showing that online learners identified student-lecturer interaction as the most important driver of engagement, while peer interaction was considered less critical (Martin and Bolliger, 2018). However, without qualitative data to support this interpretation, these conclusions remain speculative.

Taken together, these findings indicate that the game-based seminar was the only format to consistently achieve high levels of both engagement and teamwork across the years studied. While online delivery in 2020–21 yielded engagement ratings similar to the game-based seminar, and in-person delivery in 2021–22 modestly improved teamwork, only the integrated game-based activity fostered both outcomes simultaneously. This highlights the unique potential of the game format to support both student motivation and collaborative learning in a way that other formats did not replicate.

Collectively, our results show that a team-based adaptation of the game "Who Wants to Be a Millionaire?" can be used as an effective teaching activity to enhance student engagement and teamwork skills, while reinforcing knowledge of immunology at a level comparable to a standard seminar with open-ended group discussions. These findings suggest that incorporating game-based learning activities into curriculum design offers valuable opportunities for educators to promote active student participation and teamwork skills development in STEM subjects. Further research should explore the long-term impact of game-based learning on student performance and its applicability across different educational settings.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Faculty of Medical Sciences (FMS) Research Ethics Committee (REC). The studies were conducted in accordance with the local legislation and institutional requirements. The ethics committee/institutional review board waived the requirement of written informed consent

for participation from the participants or the participants' legal guardians/next of kin because verbal consent was obtained from students to use the collected anonymous data for further analysis. Given the time constraints of the seminar, obtaining written consent would have reduced the time available for the learning activity. Additionally, as no identifiable information was collected, verbal consent was deemed sufficient and appropriate for this study.

Author contributions

AI: Methodology, Investigation, Conceptualization, Writing – review & editing, Writing – original draft, Formal analysis.

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Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declare that Gen AI was used in the creation of this manuscript. Specifically, AI-assisted tools were employed to identify potential references, proofread the text, and improve readability. All references suggested by AI were reviewed for accuracy and relevance. The author(s) take full responsibility for the content, ensuring its integrity and adherence to academic standards.

Publisher's note

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