JUTLP
Journal of University Teaching & Learning Practice

Effects of Gamification and Teamwork on Students' Performance in Summative Assessments for First-Year Biology During the COVID-19 Pandemic

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Abstract

First-year undergraduate students often struggle with summative assessment in higher education due to the increased cognitive and psychomotor demands. Moreover, social isolation due to the COVID-19 pandemic exacerbated students' struggles in completing the assessments. This study explored the effects of gamification and teamwork on students' performance and learning experience during the pandemic. A total of 1,399 students completed both individual and group summative assessments; 321 of them completed a gamified group assessment. Non-parametric analyses revealed that students performed better in group assessment than in individual assessment. Piecewise Structural Equation Modelling revealed that the performance in gamified-group assessment was associated with personal feelings, perception of assessment, self-confidence, bondedness and peer interaction. Qualitative analysis confirmed that these factors shape students' learning experiences. These findings suggest the value of gamifying assessments in fostering psychological and social conditions that support learning. This study highlighted the implications for assessment design in higher education, particularly for supporting first-year students in socially constrained learning environments.

Editors

Section: Curriculum and Assessment Design
Senior Editor: Jean-Baptiste Souppez
Associate Editor: Victoria Nicholas

Publication

Submission: 20 December 2024
Revised: 4 May 2026
Accepted: 11 September 2026
Online First: 14 November 2026

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Practitioner Notes

1. Gamification influences learning through psychological mechanisms (e.g., interaction, confidence).
2. Peer interaction and bonding underpin students' confidence in completing assessments and, therefore, are key pathways to linking assessment design to learning experience.
3. Consider designing summative assessments that promote peer interaction and group bonding.
4. Consider creating positive emotional learning environments, as students' feelings toward assessment influence their learning experience.
5. Consider incorporating meaningful game elements to enhance students' perception of assessment (e.g., group identity, competition, recognition).

Keywords

collaborative learning, student motivation, peer interaction, learning experiences; summative assessment

Citation:

Lim, V.C., Hiscox, T., Azman, A.S., & Song, K. P. (2026). Effects of Gamification and Teamwork on Students' Performance in Summative Assessments for First-Year Biology During the COVID-19 Pandemic. *Journal of University Teaching and Learning Practice, 23(4)*. https://doi.org/10.53761/jv7r7x10

Introduction

There is an increasing use of collaborative learning in classroom education to prepare students for a team-based working environment in the future (Fredrick, 2008; Retnowati et al., 2017; Loes et al., 2017; Tan et al., 2018). Collaborative learning refers to when two or more people attempt to learn something together, which often involves an exchange of ideas to solve problems with equal opportunities (Retnowati et al., 2017). The social constructivist theory by Lev Vygotsky posits that knowledge is constructed in social interactions, whereby learning occurs when students actively engage peers in a range of joint activities to discuss ideas, co-construct understanding and scaffold problem-solving processes (Davis et al., 2017; Palincsar, 1998; Schreiber & Valle, 2013). Complementing this is the social interdependence theory which posits that the outcomes of individuals are affected by their own and others' actions, whereby students demonstrate higher achievement and stronger motivation when they perceive that their success depends on one another and share the same goals (Johnson & Johnson, 1994; 2009). Therefore, in a collaborative learning environment, the development of cognitive skills depends on peer interactions and students share the same responsibility and hence work together to achieve common goals.

Collaborative learning can increase academic achievement as group members are pressured by the shared responsibility and group accountability (Johnson & Johnson, 2009; Scager et al., 2016). When one’s performance affects the group’s outcomes, and they do not wish to receive negative feelings from their peers, they feel responsible for contributing to the group. Furthermore, collaborative tasks can foster self-efficacy and confidence, as group members provide feedback and help as well as provide opportunities to practise and execute arguments and suggestions (Topping, 2005; Scager et al., 2016). Collaboration also distributes tasks among group members, therefore reducing individual workload and enabling individuals to work together on more complex and ambitious assignments as a group (Scager et al., 2016). Despite its pedagogical benefits, collaborative learning is accompanied by several challenges such as inequitable workload distribution. Group members who contributed less received equal credit, therefore creating perceptions of unfairness and dissatisfaction (Burdett, 2007; Hammar Chiriac, 2014; Le et al., 2018). High-performing members may feel burdened by the need to support weaker group members, resulting in resentment and decline in motivation (Oakley et al., 2004; Le et al., 2018). Interpersonal conflicts, communication breakdowns, and coordination difficulties can further complicate the tasks and negatively affect the learning experiences (Luo et al., 2021). Concerns over grading fairness also emerge when individual contributions are not adequately differentiated within group assessment structures (Burdett, 2007). Nevertheless, collaborative learning remains an important pedagogical approach and should be explored for preparing students for real-world teamwork and professional collaboration.

One approach to facilitate collaborative learning is through experiential learning, a process where participants collaboratively (i) learn about the subject by applying their knowledge to tackle challenges that simulate real-life scenarios, (ii) make decisions with consequences, and (iii) receive feedback for their decisions (Kiili, 2005; Tan et al., 2018; Morris, 2020). It involves inquiry-driven learning situated in authentic contexts, with reflection acting as a central mechanism that transforms experience into meaningful knowledge and guides subsequent action. Peer learning and support can also be fostered through the combined approaches of collaborative learning and experiential learning, where experienced participants guide their weaker peers in acquiring

knowledge and skills, which can have positive effects on the latter's performance in the challenges (Topping, 2005; Dancer et al., 2015). In higher education, experiential learning often provides opportunities for students to develop problem-solving skills, decision-making abilities, and transferable competencies through meaningful, practice-oriented activities.

At tertiary education institutes (i.e. universities), many first-year undergraduate students in biological sciences struggle with preparing and presenting scientific reports. This may be attributed to the need for analytical, interpretative, and presentation skills, which are different from the skills required to prepare scientific reports during secondary education. This transition from secondary to tertiary education was also exacerbated by the sudden transition to the digital and remote classroom in early 2020 due to the COVID-19 pandemic (Slivkoff et al., 2021; Andersen et al., 2022). For many students, this was overwhelming, especially because they received limited peer support and access to resources due to the COVID-19 lockdown and social isolation, and they experienced anxiety and depression regarding their academic performance (Hamaideh et al., 2022; Liyanage et al., 2022). While discussion forums in the learning management system (i.e. Moodle) and online revision sessions were provided to students as additional support, only a few students utilised the forums and attended the online sessions despite being given anonymity (first author, pers. obs.). This suggested the need for a different pedagogical method that can provide emotional and social support to the students in addition to maintaining their intrinsic learning motivation.

In such remote and socially isolated learning contexts, where students are experiencing declining learning motivation and engagement, gamification can enhance students' motivation, participation, and overall learning experience (Sailer & Homner, 2020). Gamification is the use of game elements in non-game educational settings to influence learners' motivation, behaviour, and engagement (Deterding et al., 2011). Rather than transforming learning into a complete game, it embeds game-like elements (e.g. competition, rewards, points, narratives, role-playing, structured challenges, and progression systems) into instructional activities, therefore fostering engagement, a sense of achievement, and social interaction (Landers, 2015; Sailer & Homner, 2020). The "Theory of Gamified Learning" by Landers (2015) posits that game elements indirectly produce learning through (i) mediation whereby game elements influence specific learner behaviours or attitudes and consequently result in improved learning outcomes, and (ii) moderation, whereby the instructor or lesson designer improves the existing instructional content for encouraging the learner behaviours or attitudes that can increase the learning outcomes. Importantly, the theory emphasises that gamification cannot compensate for poor instructional design but enhances learning only when it successfully targets behaviours that are already known to contribute to effective learning. Unlike serious games, which are fully developed game environments that deliver instructional content directly through gameplay and acting as a mode of instruction, gamified learning incorporates selected game elements into existing learning activities to influence learners' motivation, engagement, or behaviour rather than teaching content directly (Deterding et al., 2011; Landers, 2015). Although both serious games and gamification aim to enhance learning outcomes, serious games facilitate learning through immersive gameplay, whereas gamification enhances the effectiveness of instructional content by making the learning experience more engaging.

Gamified learning has been demonstrated to enhance student engagement, motivation, participation, and enjoyment, while also fostering collaborative interaction and active learning

(Sailer & Homner, 2020; Subhash & Cudney, 2018). For example, gamified classroom environments incorporating competition and rewards have been shown to improve students' behavioural engagement and perceived learning experience. However, gamified learning may also result in negative effects such as overreliance on extrinsic rewards, increased anxiety due to competition, and uneven engagement among students (Hanus & Fox, 2015). In collaborative contexts, group size can influence learning outcomes; small groups of approximately three to five students are often more effective in promoting participation, coordination, and equitable contribution, while minimising social loafing and conflict (Gillies, 2016; Oakley et al., 2004). Moreover, game elements can significantly influence learning outcomes. Social elements (i.e. teamwork and group identity) foster interaction and collaboration among learners, thus fostering engagement and knowledge construction through peer learning (Deterding et al., 2011; Sailer & Homner, 2020). Competitive elements (i.e. leaderboards) can enhance engagement through social comparison, although their effects vary depending on individual differences among learners (Hanus & Fox, 2015; Sailer & Homner, 2020). Achievement-related elements (e.g. points, badges, and progress indicators) provide immediate feedback and reinforce learners' sense of competence, hence supporting motivation and performance (Sailer & Homner, 2020; Landers, 2015). With clear objectives and an appropriate level of difficulty, structured challenges and goal-oriented tasks can encourage persistent active engagement (Sailer & Homner, 2020). Narrative and role-playing elements support experiential learning processes, allowing learners to engage more deeply with the content (Landers, 2015; Deterding et al., 2011). Therefore, the success of gamified learning depends not only on the thoughtful instructional design, but also on group structuring and inclusion of appropriate game elements in alignment with learning objectives.

Method

Research Design

This study aims to examine the effects of gamification and the underlying psychological mechanisms on students' academic performance. We hypothesised that gamification, when coupled with teamwork, can increase the interactions and bondedness among group members. This can provide peer support to students who were socially isolated at that time, consequently supporting their learning experience and motivating them to perform better in the assessment. Therefore, the objectives of this study were (1) to determine whether students perform better in individual or group assessment, (2) to assess whether students perform better in gamified-group assessment or didactic-group assessment, and (3) to identify the variables that influence their performance in the gamified-group assessment based on their responses to the questionnaire survey and focus group discussion.

Consequently, this study employed a mixed-methods research design. Students' assessment performance was compared using non-parametric tests, while relationships among questionnaire-derived variables were examined using Piecewise Structural Equation Modelling (PSEM). Qualitative responses from open-ended questionnaire items and focus group discussions were analysed thematically to provide further insights into students' perceptions and learning experiences.

Participants

Ethical approval was obtained from the Monash University Human Research Ethics Committee for the methodology and questionnaire of this study (Project ID: 29914), which follows the Australian Association for Research in Education (AARE) Code of Ethics. The questionnaire surveys and focus group discussions of this study were advertised to undergraduate students who were aged 18 and above and were taking the first-year biology subject at the Australia and Malaysia campuses of Monash University in 2021. They were first briefed about the purpose of the questionnaire surveys and focus group discussions, the potential benefits and risks of the activities to them, their right to withdraw, and their responses will be anonymised and will not affect their marks and grades. The anonymity was for minimising social desirability bias (i.e. favourable self-presentation) and encouraging honest responses (Singer et al., 1995). Their subsequent participation in the questionnaire surveys and focus group discussions was considered informed consent. After the questionnaire surveys and focus group discussions, all responses were anonymised and stored in a password-protected external hard disk as a form of privacy and data protection. Only the first author has access to the data and external hard disk.

The total cohort consisted of 1,399 first-year undergraduates enrolled in a university that has campuses in Australia and Malaysia (Australia: N=1,078; Malaysia: N=321). All completed the summative assessments as part of the course requirements. For the questionnaire survey, a voluntary convenience sampling approach was employed, resulting in only 35 usable responses from the Malaysia campus (10.9% response rate). Of these, only six respondents completed both pre- and post-surveys, and hence, for such a case, only one response to the pre-survey was retained.

Design of the Assessments

In 2021, when the lessons were conducted in a hybrid mode (either online or physical) in response to to the COVID-19 pandemic, we gamified a group assessment for first-year undergraduate students in biological sciences. Students were instructed to conduct a literature review of a biological topic and present their findings visually and orally as a group. To encourage students' participation and minimise the effects of social isolation, we attempted to gamify the group summative assessment. We explained to students that the gamified group assessment simulates a real-life scenario where a team of researchers attempt to convince the journal reviewers to accept their research manuscript for publication. We also informed students that the gamified group summative assessment contributes 6% to the final course grade (total = 100%). Marks awarded to each group were shared equally among members with no individual differences. Therefore, this design aligns with the previously discussed theories:

i. **Social interdependence theory**, as all group members shared the same goals and their participation in the group assessment influenced the resulting marks

ii. **Social constructivist theory**, as students are required to actively interact with each other to complete the tasks in the group assessment

To examine the effects of gamification and teamwork on the students' academic outcome, we compared the following: (i) individual versus group assessments, and (ii) didactic-group versus gamified-group assessments. Details of the assessment design and cohort structure are provided in Table 1. For the individual assessment, students were informed that marks would be awarded

solely based on their individual performance and would contribute 8% to the final course grade. The assessment was completed independently in a didactic manner, following the provided written instructions. For the group assessment, students were divided into two cohorts based on the assessment design at their respective campuses: (i) a didactic-group assessment implemented at the Australia campus, which served as the control, and (ii) a gamified-group assessment implemented at the Malaysia campus, which served as the treatment. The control cohort received written instructions and completed the task in a didactic manner. In contrast, the treatment cohort completed the assessment within a gamified environment, which included game-based instructions, recognition of top-performing groups, allocation into themed “houses” with emblems to foster competition, and a visually enhanced learning management system (Table 2).

The Treatment cohort completed the group assessment within a gamified framework comprising multiple elements designed to influence students’ engagement, motivation, and learning experience (Table 2). First, a game plan and scenario-based narrative framing were introduced to present the assessment as a structured yet engaging activity, which was intended to enhance students’ engagement, positive feelings, and self-confidence when approaching the task (Figure 1). Students were organised into small groups of three or four members and assigned to thematic houses, forming the basis of an interhouse competition in which group marks contributed to cumulative house scores (Figure 2). This structure was designed to promote social identity, belonging, and interaction among students, thereby enhancing bonding and collaborative engagement. Each house was represented by emblems, providing a visual identity to further strengthen group cohesion and encourage interaction among members. To encourage participation, a penalty mechanism was implemented whereby students who did not contribute to the group assessment received lower marks as a group, promoting accountability and discouraging free-riding behaviour. This performance-based marks also served as an extrinsic reward, reinforcing active participation and contribution as tangible academic outcomes. In addition, an intrinsic reward was introduced through the recognition of top-performing teams in an e-book, which aimed to enhance students’ sense of achievement, positive feelings, and self-confidence without directly affecting grades (Figure 3). Finally, the learning management system (i.e. Moodle) was visually enhanced using thematic and game-like elements to create an immersive and aesthetically engaging environment, thereby increasing students’ interest and positive affect toward the assessment (Figure 4). Collectively, these gamification elements were designed to influence multiple motivational constructs (i.e. activities, feelings, self-confidence, interaction, and bondedness) through mechanisms grounded in gamification theory, self-determination theory, and social identity theory (Table 2).

Due to the campus-based segregation, the interaction between the two cohorts was minimal. Although this design resulted in unequal sample size and differences in the learning environment, the assessment content and grading criteria were standardised across both cohorts. Furthermore, Kruskal-Wallis Rank Sum Test indicated no significant difference in group assessment marks between the two cohorts (see Results section), suggesting comparability in performance outcomes. Note that before the group assessment, both cohorts had participated in group discussions of case studies during classes, either through randomised breakout rooms during online sessions or seating-based grouping during face-to-face sessions. Therefore, it is possible that students in a specific cohort already have some form of social interaction and hence peer bonding before participating in the group assessment.

Table 1

Design of the Assessments and Cohorts to Examine the Performance of Students in Various Assessments and the Variables That Influence the Performance in Gamified-Group Assessment

Objectives	Design	Statistical analyses	Cohort
Whether students perform better in individual or group assessment	Each student completed (i) individual and (ii) group assessments. Individual assessment: student prepared a 500-word extended abstract for an experiment about microbial growth with limited resources. Group assessment: student presented the given topic (Figure 2), orally and visually within 15 minutes as a group of ≤4 members.	Paired Wilcoxon Signed Rank Test to compare the marks between individual and group assessments from the same student.	Control (N=1078): Didactic-individual assessment Treatment (N=321): Didactic-individual assessment
Whether students perform better in gamified-group assessment or didactic-group assessment	Control cohort: group assessment was based on didactic instructions. Students received written instructions and prepared a standard presentation slide to support their oral presentation. Treatment cohort: group assessment was gamified. Students received a game plan, prepared a poster to support their oral presentation, and participated in an interhouse competition.	Kruskal-Wallis Rank Sum Test to compare the marks between Control and Treatment cohorts	Control (N=1078): Didactic-group assessment Treatment (N=321): Gamified-group assessment
Variables that influenced Treatment cohort's performance in gamified-group assessment	Treatment cohort: questionnaire surveys and focus group discussions were conducted with students to obtain their feedback about the gamified-group assessment.	Piecewise Structural Equation Modelling to identify the explanatory variables.	Treatment (N=35): Respondents voluntarily shared their feedback regarding the gamified-group assessment

Figure 1

The game plan that was provided to the Treatment cohort to brief them about their gamified group assessment. Penalty and rewards were introduced in the game plan to foster their motivation.

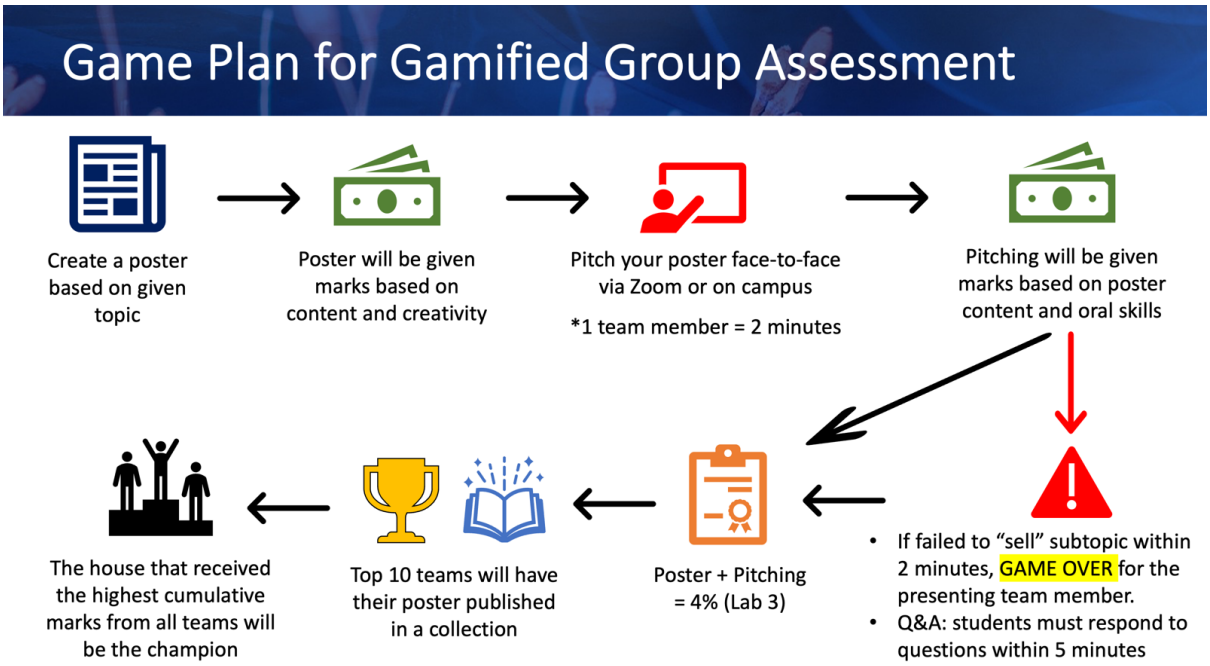


Figure 2

The six houses with respective emblems representing the six topics in the gamified group assessment. Students in the Treatment cohort were segregated into teams of three or four members. Each team was given a specific topic to present, and therefore represented a house. As part of the interhouse competition, each team must collect as many marks as possible from their group assessment to contribute to the cumulative marks for each house.



Figure 3

Excerpts of e-book which served as intrinsic reward for students who performed well in the gamified group assessment. The e-book contains posters from ten teams who received highest marks and therefore, contributed most to their respective house in the interhouse competition.

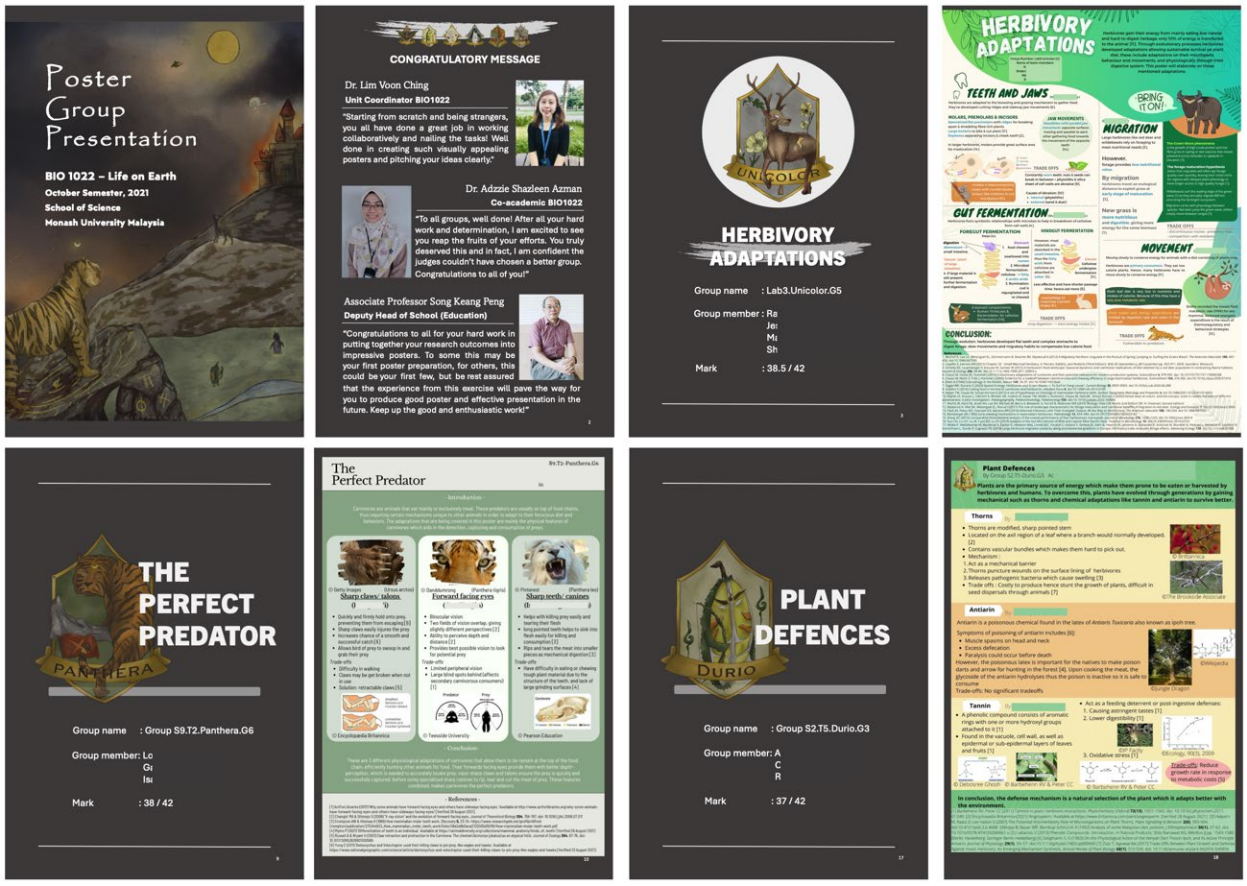


Figure 4

The learning management system was decorated with the emblems to promote interhouse competition

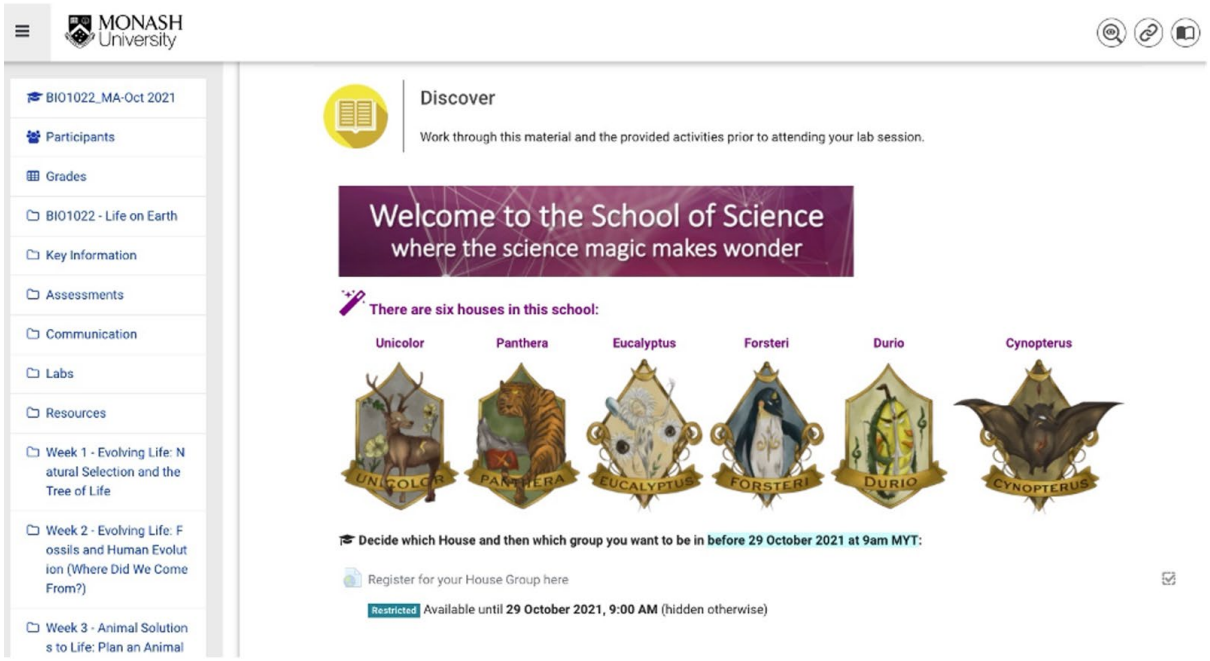


Table 2

Game Elements in the Gamified Group Assessment for the Treatment Cohort

Game elements	Implementation	Intended Mechanism	Theory	Construct	Hypothesis
Game plan	Narrative framing	Engagement	Gamification theory	Activities; Feelings; Self-confidence	• Students perceive the group assessment positively as a fun group task after receiving the game plan • Students feel positively such as being excited about the group assessment after reading the game plan • Students have higher self-confidence when completing the group assessment after knowing the structure of the group assessment
Scenario	Narrative framing	Engagement	Gamification theory	Activities; Feelings	• Students perceive the group assessment positively as a role-playing activity, whereby they are young researchers trying to convince senior researchers (e.g., lecturers) to accept their argument points through poster and oral presentation • Students feel excited about the group assessment as it is a role-playing activity
Penalty	Students who do not contribute to the group assessment receive lower marks	Promotes accountability and discourages free riding by linking individual behaviour to academic outcomes	Self-determination theory	Marks; Feelings	• Students who do not participate in, or contribute to, the group assessment will be penalised by receiving lower marks • Students feel negatively about the penalty such as being anxious as their academic performance will be affected by their actions
Extrinsic reward	Students who actively contribute to the group assessment receive higher marks as a tangible academic outcome	Reinforces desired behaviours through outcome-based incentives (e.g., participation)	Self-determination theory	Marks	• Students who participate in, or contribute to, the group assessment will be rewarded with higher marks which is tangible academic performance outcome

Game elements	Implementation	Intended Mechanism	Theory	Construct	Hypothesis
Intrinsic reward	Recognition	Competence, achievement	Self-determination theory	Feelings; Self-confidence	• Students feel excited about the acknowledgement as top performing teams in class which is intangible academic performance outcome • Students who want to be acknowledged have higher self-confidence when completing the group assessment
Interhouse competition	• Teams assigned to houses • Inter-house ranking	• Social identity, belonging • Motivation, engagement	Self-determination theory	Interaction; Bondedness	• Students who want to win the interhouse competition will have higher social interactions and bonding among team members as they work towards completing the group assessment and achieving the shared same goal
Emblems	Visual identity	Group bonding	Social identity theory	Interaction; Bondedness	• Emblems served as an identity for each house, which was intended to create a sense of belonging for each student. • Therefore, as a house member, students will have higher social interactions and thus bonding to contribute cumulative marks from their group assessment to ensure victory for their house
Decorated learning management system	The learning management system was visually enhanced using themes and game-like elements to present the group assessment	Enhances emotional engagement and perceived enjoyment by creating visually appealing learning environment to increase interest	Gamification theory	Activities; Feelings	• Students perceive the group assessment positively as a fun group task after seeing the aesthetic visuals on their learning management system • Students feel positively such as being excited about the group assessment after seeing the aesthetic visuals on their learning management system

Analyses of Students' Performance

All the statistical analyses here were conducted in R version 4.2.2 (R Core Team, 2022) and are available as Supplementary Information 1. Firstly, the marks awarded to all students for their individual and group assessments were extracted from the learning management system, representing "Marks". Shapiro–Wilk test from the package "rstatix" (Kassambara, 2022) indicated that the marks for both individual and group assessments were not normally distributed ($p<0.05$). Therefore, non-parametric tests from the package "rstatix" (Kassambara, 2022) were used here; (1) paired Wilcoxon signed-rank test to compare the students' "Marks" between their individual and group assessments, and (2) Kruskal-Wallis rank-sum test to compare the group assessment "Marks" between Control and Treatment cohorts (Table 1).

Analyses of Gamification and Teamwork Effects

A questionnaire was designed following Tan et al. (2018) and distributed to the Treatment cohort via Google Form before and after the gamified group-assessment for pre- and post-evaluation. The statements and the questions in the questionnaire are summarised in Table 2 and detailed in Supplementary Information 2. A pictorial smiley scale was used as options for responses to (i) the question to encourage substantive responses within a short processing time and (ii) counter online fatigue due to the pandemic lockdown (Toepoel et al. 2019; Lim et al., 2023, Richter et al. 2023). Moreover, the smiley scale was used because (iii) emojis are commonly used in instant messaging, (iv) pictorial icons save space on small mobile device screens compared to text (Toepoel et al. 2019). The smiley responses were then converted into a 5-point Likert scale (i.e. wide grin = 5 whereas frown = 1). Given that a wide smile generally displays a highly positive emotion compared to a smile, we considered that the former represents a "strong agreement" with our statement compared to the latter which represents just an "agreement", corresponding to "5" and "4" respectively. The negative statements were also reverse scored. However, the questionnaire surveys received a poor response rate, likely attributed to the fatigue of online classrooms during the COVID-19 pandemic, with only six students completing both "before" and "after" questionnaires; for these six cases, only the "before" responses were retained. In the case where only "after" responses were recorded, this single response was retained. This resulted in 35 responses, which were used in the following analyses.

Five variables (i.e. "Activities", "Feelings", "Self-confidence", "Bondedness", and "Interaction") were elicited from the 35 responses to the questionnaire (Table 3). For "Activities" and "Feelings", the calculated Cronbach's Alpha (package "psych", Revelle, 2022) for the responses to the representative four statements were >0.8, indicating high internal consistency (Tavakol & Dennick, 2011) and therefore, the responses were averaged to represent that specific variable (Table 2). The high Cronbach's Alpha values also indicated that the conversion of the smiley scale to 5-point Likert scale did not affect the internal consistency of the responses. However, for "Self-confidence", the calculated Cronbach's Alpha for the representative four statements were consistently <0.7, indicating low internal consistency. Therefore, only one most straightforward statement was used to represent "Self-confidence". For "Bondedness" and "Interaction", the ratings given by the respondents to all members of their team were averaged to represent that specific variable.

Following Lim et al. (2022), linear modelling and multi-model inference (from package “MuMIn”, Bartoń, 2022) were performed on the 35 responses to choose the best models with the lowest Akaike information criterion (AIC), lowest delta AIC and highest AIC weight for identifying explanatory variables that influence the response variables associated with the gamified-group assessment. The top five models resulting from multi-model inference were fitted into the Piecewise Structural Equation Model (PSEM) (using package “piecewiseSEM”, Lefcheck, 2016) to create an overarching model that best explained the pathways of all identified variables that influenced the student’s performance in the gamified-group assessment. The PSEM model fulfilled these criteria: (i) all variables were independent based on tests of directed separation (all p-value > 0.05), and (ii) no potential missing paths based on Fisher's C test (9.04, p-value = 0.96, df = 18). Post hoc assessments (from package “lavaan”, Yves, 2012) also supported the PSEM’s goodness of fit (CFI = 1, TLI = 1.123, RMSEA=0, SRMR, 0.024).

To support the statistical results, the treatment cohort which received gamified-group assessment was invited to a focus group discussion conducted through an online conference call (www.zoom.com/). Six students who participated were requested to switch off their cameras and rename themselves to “Student” to minimise any bias to the responses (e.g. peer pressure, anonymity and safe space. Open-ended questions were provided on Jamboard to guide the group discussion (Supplementary Information 3) including (1) their feelings when completing the assessment, (2) encountering and solving the problems related to the assessment, (3) the extent of their liking and disliking for the assessment, and (4) room for improvement. The audio recording of the discussion was transcribed. The transcript, the responses on the Jamboard, and students’ responses to the open-ended questions in the questionnaire were thematically analysed.

Results

The Control cohort, which completed all assessments in a didactic manner, performed significantly better in their group assessment than their individual assessment (N = 1078, Wilcoxon Signed Rank Test = 30591, p<0.00; Figure 5). Likewise, the Treatment cohort, which completed their group assessment in a gamified setting, performed significantly better in their group assessment than their individual assessment (N = 321, Wilcoxon Signed Rank Test = 1493, p<0.00; Figure 5). However, there was no significant difference in the marks for group assessment between the Control (median = 82.15%) and Treatment (median = 80.95%) cohorts (N=1399, Kruskal-Wallis rank-sum test = 0.11, p=0.74; Figure 5).

PSEM of the 35 responses revealed that higher “Marks” were positively influenced by more positive “Feelings” when completing the gamified-group assessment (p<0.01, (i) in Figure 6. Positive “Feelings” were positively influenced by more positive perception of “Activities” (p<0.01, (ii) in Figure 6) and higher “Self-Confidence” (p<0.01, (iii) in Figure 6). The latter two variables had significant positive associations; higher “Self-Confidence” was influenced by a more positive perception of “Activities” (p=0.01) and vice versa (p=0.01, (iv) in Figure 6). Higher “Self-Confidence” was significantly, albeit weakly, influenced by stronger “Bondedness” among the group members (p=0.04, (v) in Figure 6). Stronger “Bondedness” was positively influenced by higher “Interaction” among the group members (p<0.01, (v) in Figure 6). These findings support the mediation pathway proposed in the Theory of Gamified Learning (Landers, 2015), whereby game elements can influence learning through psychological mechanisms (e.g. feelings,

engagement). Furthermore, these findings also reflect the principles of social interdependence theory, whereby interaction and bondedness can contribute to individual performance outcomes.

Table 3

*The Variables That Are Represented by Statements and Questions in the Questionnaire Survey and Used in Linear Modelling and Piecewise Structural Equation Modelling. Asterisks * Indicate Negative Statements That Were Reverse Scored with a 5-Point Likert Scale.*

No.	Variables	Explanation	Cronbach alpha value
1.	Activities	Perception of the activities in the gamified-group assessment. The statements were: • Preparing the assignment was enjoyable • The assignment was fun • *I don't think the preparation of the assignment was a pleasant experience • *I think the assignment was boring	0.893
2.	Feelings	Personal feelings when completing the gamified-group assessment. The statements were: • I felt excited when preparing the assignment • I felt relaxed when preparing the assignment • *I felt anxious when preparing the assignment • I did not feel nervous at all when preparing the assignment	0.828
3.	Self-confidence	Self-confidence when completing the gamified-group assessment. The statement was • *I didn't feel confident in completing the assignment	Not calculated
4.	Bondedness	Bondedness among group members. The question was: • How close you are to other members after the assignment? Rate from one="not close at all" to five="very close"	Not calculated
5.	Interaction	Interaction between group members. The question was: • How much do you know about other members after the assignment? Rate from one="not at all and never interacted before" to five="a lot and considered very close"	Not calculated
6.	Marks	Extracted from the learning management system. Marks awarded to students for their individual and group assessments	Not calculated

Figure 5

Comparison of the marks for individual and group assessments between the Control and Treatment cohorts. Red p value represents the comparison between individual and group assessments within the Treatment cohort, blue p value represents the comparison within the Control cohort, whereas black p value represents the comparison between the Control and Treatment cohorts for both assessments.

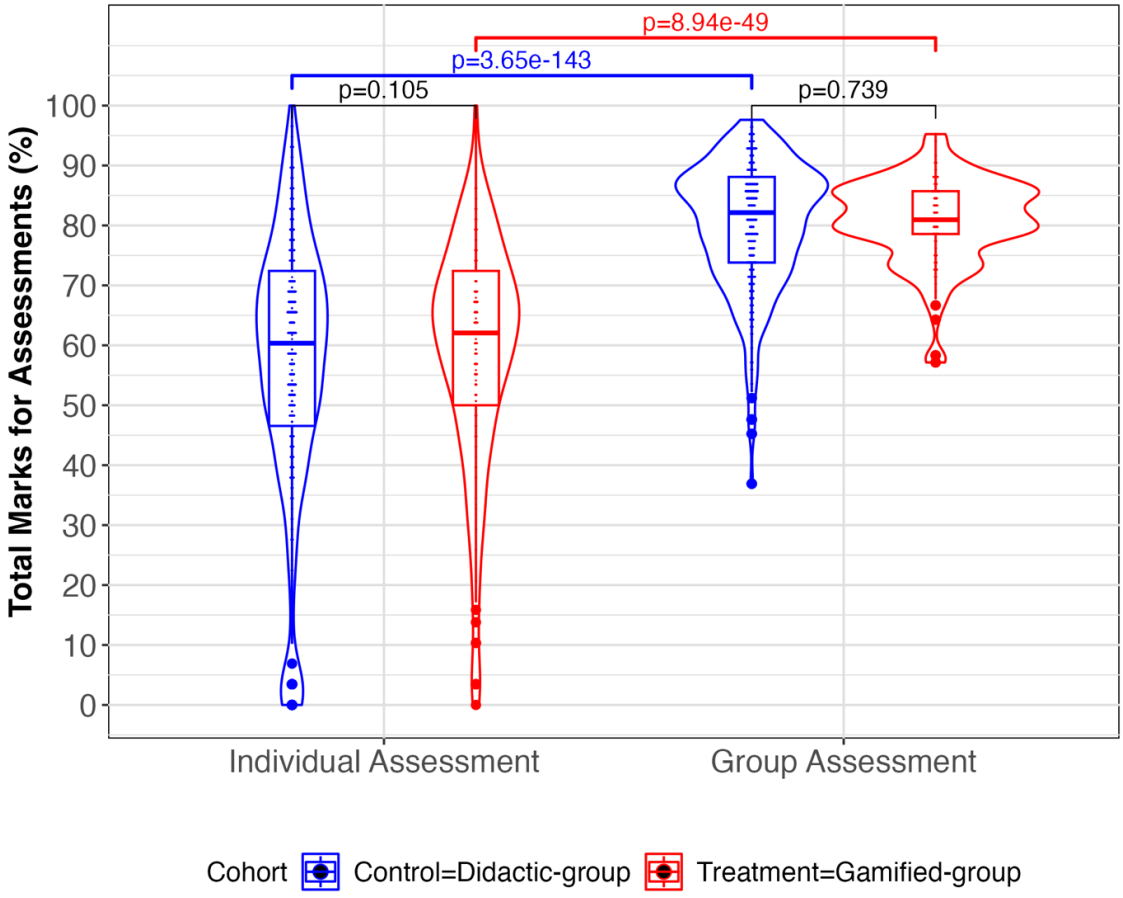
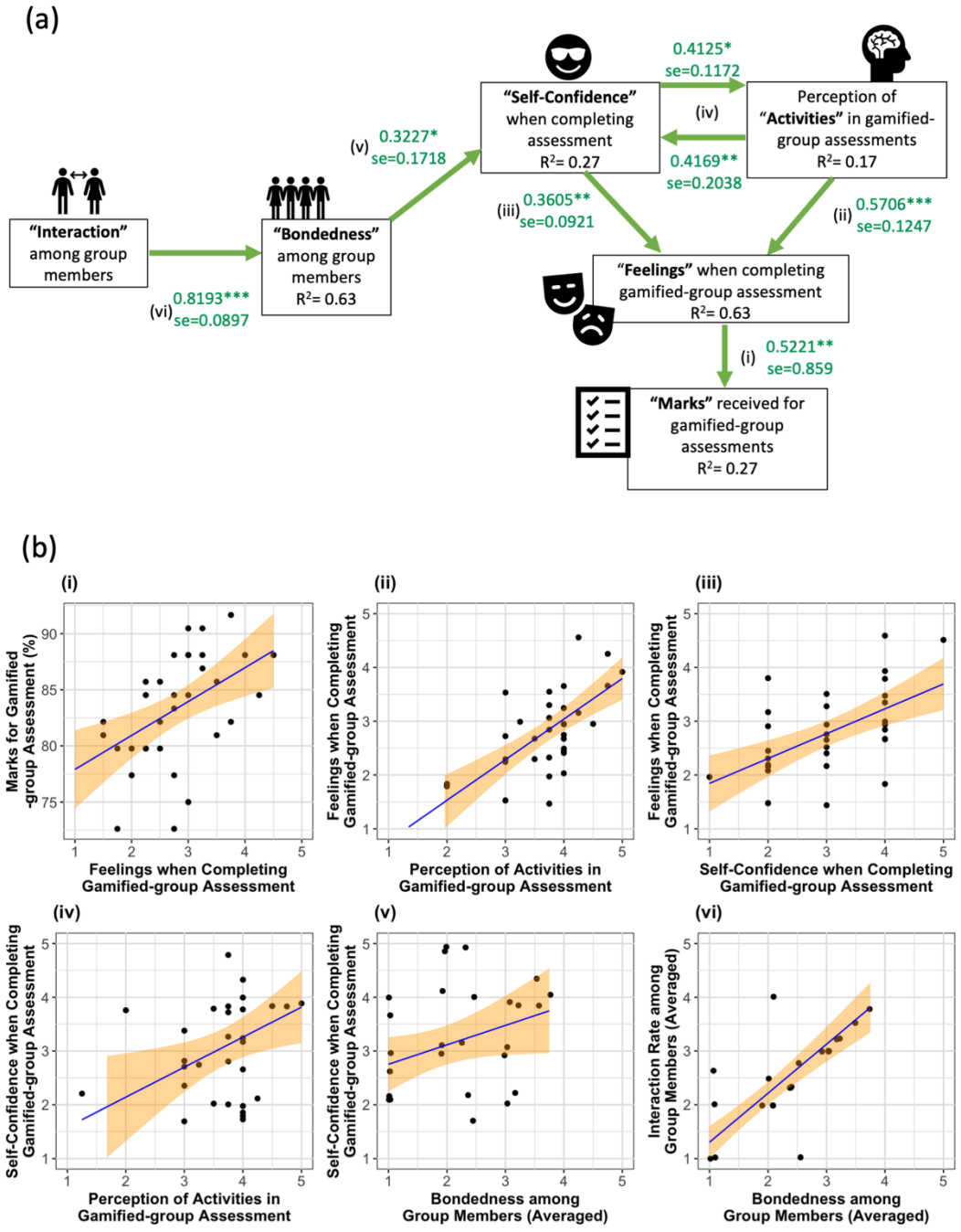


Figure 6

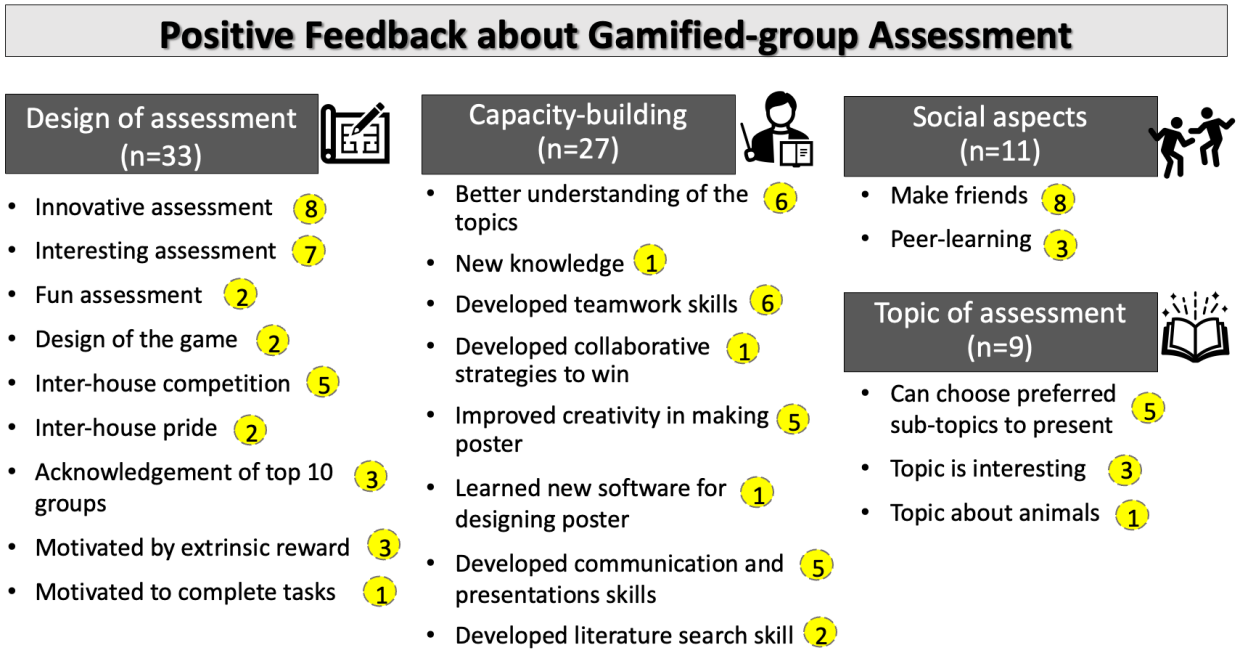
*Pathways of relationships between all variables associated with the gamified-group assessment, where the Roman numbers in (a) correspond to those in (b). (a) Piecewise Structural Equation Model showing the relationships for all variables based on coefficient estimates. Arrowhead indicates the unidirectional positive relationship where the explanatory variable influenced the response variable. Asterisks represent the significance levels of p-values in increasing order: *=p<0.05, **=p<0.01, and ***=p<0.001. se indicates standard error, whereas above se is coefficient estimates. (b) Visualisation of relationships between variables based on the chosen five linear models. A line of best fit (blue) with a 95% confidence interval (orange) was plotted.*



The feedback from focus group discussions and questionnaire surveys provided insights into what could have constituted the specific variables that best explained the students' performance in the gamified-group assessment (Figure 7). The gamified-group assessment facilitated "Interaction", as students made new friends, learned from their peers, and worked in a team. This may have consequently fostered "Bondedness", as students instilled interhouse pride, wanted to be the top-performing groups, and developed teamwork skills and collaborative strategies to achieve this goal. Having team members to support them may have also boosted their "Self-Confidence". Such group assessment also helped students to understand the topics better and develop new skills, and since they had the autonomy to choose sub-topics (e.g. specific animals or plants) to work on, which altogether could have boosted their "Self-Confidence". As for the "Activities", students perceived the gamified-group assessment to be innovative, interesting, and fun, likely due to the interhouse competition and acknowledgement of top-performing groups. Overall, this could have reinforced their positive "Feelings" when completing the assessment and hence influenced their performance in the gamified-group assessment.

Figure 7

Students' positive feedback about the gamified-group assessment, which was thematically summarised based on their responses to the questionnaire and focus group discussion. The number in the yellow circles and "n" indicate the number of responses that are under each specific point.



Discussion

Although gamification did not significantly improve performance outcomes, it influenced key psychological processes that underpin learning. In this study, we examined how gamification shaped learning through peer interaction, group bonding, self-confidence, and students' emotional experiences. We also discussed how these findings can inform the design of summative assessments that foster meaningful learning experiences, particularly for first-year students transitioning into higher education.

Effects of Gamification on Group Assessment

We did not find significant effects of gamification on the students' performance (i.e. marks) for the group assessment, which may be explained by two factors. Firstly, the Control cohort was instructed to prepare a presentation slide for the final presentation, whereas the Treatment cohort was instructed to prepare a poster (Table 1). While this difference was intended to explore the "vibrant and fun" aspects of the poster as an assessment, we were strict in minimising the discrepancy of mark distribution between the two cohorts by using a standard marking rubric. Secondly, while we maintained cross-campus marking for the earlier activities in the group assessment, we separated the marking for the final presentation. The two cohorts were assessed by two different groups of evaluators for the presentation due to the challenging logistics associated with the large size of the two cohorts combined (n=1399). Therefore, the assessment of the presentation by different evaluators may have influenced the marks received by the students.

Collaborative Assessment Provides Peer Support and Learning

It is worth noting that our study took place during the COVID-19 pandemic in 2021 and the learning sessions for the students at that time were conducted online and remotely, where students were socially isolated. Andersen et al. (2022) reported that the academic performance of medical students at the University of Nevada, Las Vegas dropped during the isolation period of the COVID-19 pandemic, which can be attributed to isolated studying as it hindered deeper discussion with peers and understanding of the knowledge. In our study, we found that students performed better in the group assessment than in the individual assessment. Note that the students in this study were in their first year of tertiary education, which can be a challenging transition from secondary education. Hence, they would benefit from the emotional and learning support from their peers (Slivkoff et al., 2021; Andersen et al., 2022). As the pandemic had socially and physically isolated the students, our group assessment provided opportunities for them to interact and bond with each other positively (i.e. making friends and learning from peers). Having such peer support not only boosted their confidence but also provided emotional support when completing the assessment. This is also likely to be facilitated by peer learning, where students who perform better academically could have guided their weaker peers in completing the assessment (Dancer et al., 2015). Therefore, the group assessment may have positive effects on students' academic performance through collaborative learning, which can facilitate their persistence in their study (Natoli et al., 2014; Loes et al., 2017).

Factors Influencing Performance in Group Assessment and Recommendations

Although we did not find significant effects of gamification on students' performance, we received positive verbal feedback from students regarding the gamified-group assessment. Firstly, the students were segregated into groups representing specific houses to create a sense of belonging, and they were informed of a non-academic reward where the top-performing groups would be acknowledged in the class. Such a design of the assessment may have fostered the students' positive perception of the activities (i.e. "innovative", "interesting", "fun", and "competitive" as quoted). Therefore, the gamification may have encouraged the students to "engage" and "compete" in the group assessment while still learning the biological topics and polishing their presentation skills. This overall may have influenced the intrinsic learning motivation factors such as engagement and positive feelings (Tan et al., 2018; Andersen et al., 2022). Secondly, the students were instructed to create and present a poster as a group, and through the process, they acquired new skills relevant to the assessment likely to be mediated by the collaborative learning process, which can facilitate their persistence in their study (Natoli et al., 2014). Hence, such a capacity-building aspect of the group assessment may have boosted their self-confidence when completing the assessment. As demonstrated here, self-confidence in, and perception of, the assessment have direct causal links. In short, students who perceived the assessment to be enjoyable tended to be more confident in completing the assessment, and vice versa. Together, these two variables influenced one's personal feelings when attempting the assessment, which consequently affected their performance in the assessment.

Personal feelings can be an indicator of mental health status and can affect one's learning experience (Vitasari et al., 2010; Slivkoff et al., 2021; Andersen et al., 2022). Students with a high level of anxiety tend to have poor academic performance (Vitasari et al., 2010), and a lack of support and guidance from instructors can foster negative attitudes toward group assessment among students (Natoli et al., 2014). Social isolation, especially during the pandemic, can affect students mentally and consequently their academic performance (Andersen et al., 2022). Here, we found that students who had positive feelings when completing the assessment (i.e. "excited", "relaxed", "not anxious", "not nervous" as stated in our questionnaire) tended to perform better in the assessment. Therefore, the group-based assessment may have played a role in mitigating students' negative feelings arising from social isolation during the pandemic and fostered bondedness among the group members, encouraging them to help each other when completing the assessment. This could have boosted their self-confidence and reinforced their positive feelings when completing the assessment, therefore resulting in students believing that the assessment is within their capability, which can have a positive impact on their performance in the assessment (Kiili, 2005).

Altogether, these findings support the mediating role of psychological factors as proposed in the theory of gamified learning (Landers, 2015) and align with the self-determination theory, where relatedness and competence contribute to positive learning experiences. This also reinforces the theory that gamification influences learning indirectly through psychological and behavioural pathways rather than direct instructional effects. Therefore, when designing an assessment, we suggest that these to be taken into consideration for improving students' learning experience:

1. **To avoid a decline in self-confidence**: Design assessment activities to be performed in a group, which can be mediated by peer support. This also allows students to learn transferable

soft skills (e.g., communication and teamwork skills) which will benefit their academic and career prospects.

2. **To improve the perception of assessment**: Incorporate creativity and interactivity in assessments. This allows students to perceive it as “uniquely different from the usual mundane assessment” and have fun while still being acknowledged for their effort (e.g. marks and recognition in class).

Limitations of the Study

Nevertheless, this study has several limitations. Firstly, the low response rate to the questionnaire survey (n=35) is subject to bias and hence limits the generalisability of the findings. Therefore, the findings should be interpreted as exploratory and indicative of potential mechanisms underpinning effective learning. Secondly, the study was conducted during the COVID-19 pandemic, and therefore, the findings may not be fully applicable to a non-remote learning setting. Thirdly, the comparison between two different campuses introduced potential confounding variables, including differences in learning environments, different assessment formats (i.e. presentation slide versus poster), and evaluators who grade the assessments. Lastly, the absence of pre-intervention data limits the interpretation of the effects of gamification. Additionally, the voluntary nature of participation may have introduced self-selection bias, as more engaged students may be more likely to respond to the questionnaire and focus group discussion. Despite these limitations, our study provided meaningful preliminary insights into assessment design, demonstrating the potential of gamification and collaborative learning approaches in enhancing students’ learning experience.

Conclusion

Although we did not find a significant direct effect of gamification on group assessment, our findings highlighted the indirect effects of gamification through psychological and social mechanisms. Group members who interacted more with each other to complete the assessment developed a stronger bond, which was associated with increased self-confidence in completing the group assessment, likely due to having support from group members. Self-confidence and perception of the assessment have a direct causal link; when students were confident, they tended to perceive the assessment to be enjoyable, and vice versa. This contributed to more favourable emotional experiences, such as being excited and relaxed when completing the assessment, which was associated with better academic performance. Our findings, therefore, suggest that the value of gamifying summative assessments lies not only in improving academic performance, but also in shaping students’ psychological experiences, which underpin effective learning. Therefore, when designing summative assessments, we recommend prioritising elements that (i) foster peer interaction, (ii) build students’ confidence, and (iii) create engaging learning environments. Such approaches can be beneficial to first-year undergraduates who are navigating the transition into higher education, especially for ensuring academic engagement and persistence.

Acknowledgements

The authors disclose that they have no actual or perceived conflicts of interest. The authors disclose that they have not received any funding for this manuscript beyond resourcing for academic time at their respective universities. The authors disclose that this study was financially

supported by the School of Science Education Seed Grant 2021 (SED-000079), Monash University Malaysia awarded to VCL, SKP and TH. The authors have not used artificial intelligence in the ideation and design this research as per Crawford et al. (2023), other than for improving the language of the manuscript for publication. The authors confirmed that they have met the ethical standards expected as per Purvis and Crawford (2024). The authors list the following CRediT contributions: VCL: Conceptualisation, Funding Acquisition, Investigation, Data curation, Formal Analysis, Visualisation, Writing – Original Draft, Writing – Review & Editing, Project Administration. TH: Conceptualisation, Funding Acquisition, Writing – Review & Editing. KPS: Conceptualisation, Funding Acquisition, Writing – Review & Editing. ASA: Investigation, Writing – Review & Editing, Project Administration. The authors thank Brenton Marshall for his support and coordination of the learning management system (Moodle) for this study. The authors would also like to extend their gratitude to the teaching assistants of School of Science, Monash University Malaysia and School of Biological Sciences, Monash University Clayton for helping with the assessments in this study.

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