

MOVEMENT-BASED GAMIFICATION EFFECTIVENESS IN ORGANIC CHEMISTRY ACTIVE LEARNING AND RETENTION

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Abstract. Organic chemistry often presents significant learning challenges, leading to low motivation and retention among STEM students. This study evaluates the effectiveness of movement-based gamification, a non-digital, kinesthetic approach, in improving engagement and knowledge retention in an introductory organic chemistry course. Thirty diploma-level students participated in checkpoint-style, team-based activities involving time-bound problem-solving and immediate feedback from facilitators. Pre- and post-intervention surveys measured six indicators, which are enjoyment, confidence, focus, recall, teamwork, and motivation, using a five-point Likert scale. Results showed significant improvements across all indicators, with the highest gains in enjoyment (86%), confidence (51%), focus (52%), and recall of nomenclature rules (51%). The results also showed a greater relative enhancement in psychological factors (confidence, enjoyment, motivation) by 60.36% compared to behavioural factors (focus, recall, teamwork) by 49.26%. Observations and student interviews confirm enhanced motivation, collaboration, and conceptual understanding. These findings demonstrate that movement-based gamification effectively promotes active participation and deeper learning while reducing reliance on screen-based tools. The approach provides an economical and engaging alternative for teaching complex scientific topics, creating a supportive and interactive classroom environment. Overall, the study suggests that integrating kinesthetic, game-like elements into chemistry instruction can significantly improve student motivation, focus, and knowledge retention.

Keywords: *movement-based gamification, organic chemistry, active learning, kinesthetic learning, student motivation*

Introduction

Science education, particularly in chemistry, is often considered challenging due to the inherent complexity of its content, leading many students to struggle with or abandon the subject (Lutfi et al., 2023). Organic chemistry, with its intricate molecular structures, nomenclature systems, and reaction mechanisms, poses difficulties in comprehension (Sukmawati, 2020). Students frequently report that organic chemistry requires a high degree of memorization and abstract reasoning, which can result in frustration, low academic performance, and reduced interest in continuing within STEM disciplines. This perception of difficulty has been identified as a significant factor contributing to low retention rates, demotivation, and high dropout levels in chemistry-related programs (Guo et al., 2022). In recent years, active learning strategies have garnered considerable attention from educational researchers as a promising approach to enhance student engagement and foster deeper comprehension in science education. Unlike traditional lecture-based instruction, active learning encourages students to participate directly in the learning process through discussion, experimentation, and

problem-solving. Research indicates that strategies such as problem-solving exercises, hands-on activities, and peer collaboration improve students' conceptual understanding and promote long-term retention of scientific knowledge (Ng Ligado et al., 2022; Chitti et al., 2020). These approaches also cultivate a student-centered learning environment, addressing the disengagement frequently present in conventional lecture-based settings.

Gamification, which integrates game-like elements into non-game contexts, represents a novel pedagogical approach that leverages intrinsic motivation and engagement to facilitate learning (Da Silva Junior et al., 2025). It has been shown to enhance student motivation, engagement, and classroom participation in science-related subjects. Moreover, digital platforms like Kahoot! and Quizizz have proven effective in making learning more interactive, promoting active engagement, and enhancing short-term academic performance, particularly in chemistry education (Raju et al., 2021). These platforms allow students to receive instant feedback and reinforcement, which in turn promotes engagement and satisfaction during the learning process. However, screen-based gamification has several limitations. While these tools can boost immediate engagement, they often result in repetitive learning that prioritises recall over the development of a deeper understanding or collaborative learning opportunities (Furdu et al., 2017). Moreover, the use of screen-based methods can lead to extended periods of sedentary behaviour, which recent research has linked to decreased cognitive stamina and increased mental fatigue (Small et al., 2020). This raises concerns about the potential for diminished focus and attention spans, particularly when integrated into rigorous academic disciplines like organic chemistry. Therefore, exploring non-screen-based gamified approaches becomes crucial to foster active learning, promote deeper conceptual understanding, and mitigate the potential negative effects associated with prolonged screen time in complex subjects.

Emerging research suggests that integrating physical activity into learning, known as movement-based or kinesthetic learning, can significantly enhance cognitive engagement, attention span, and knowledge retention (Price and Rogers, 2004). Movement-based gamification, particularly checkpoint-style or explorace learning, incorporates active movement, problem-solving, teamwork, and game elements. This approach caters to multiple learning styles (visual, auditory, kinesthetic, and social) and creates an engaging, energised classroom environment. The combination of motion, collaboration, and challenge aligns with the principles of holistic education, in which students learn not only through mental effort but also through physical and emotional involvement. Despite the promising potential of movement-based gamification, research on its application in tertiary-level science education, particularly in organic chemistry, remains limited. Most existing studies have focused on digital gamification platforms rather than physical, non-digital methods. This gap underscores the need to examine whether movement-based gamification can improve students' understanding of complex topics, such as organic compound nomenclature and reaction mechanisms, while also promoting motivation and active participation. Therefore, this study was conducted to evaluate the effectiveness of movement-based gamification in enhancing active learning, motivation, and knowledge retention among diploma-level students in an introductory organic chemistry course. Specifically, the study sought to measure improvements in enjoyment, confidence, concentration, teamwork, and recall before and after the intervention. By analyzing students' perceptions, classroom behaviors, and qualitative feedback, this research aims to provide empirical evidence on how kinesthetic, game-like learning can enrich the teaching and learning experience in

organic chemistry. The outcomes of this study are expected to contribute to ongoing discussions on active learning innovations and offer practical insights for educators seeking to make complex STEM subjects more interactive, inclusive, and engaging.

Research question

In line with the objectives of this study, several research questions were developed to guide the investigation. (1) To what extent does movement-based gamification enhance students' active participation and engagement in learning organic chemistry? (2) How does movement-based gamification influence students' understanding and recall of fundamental organic chemistry concepts? (3) What are the students' perceptions of enjoyment, motivation, confidence, and teamwork when participating in movement-based gamified learning activities? (4) How do psychological and behavioral learning indicators such as focus, collaboration, and motivation change before and after the gamification intervention?

Materials and Methods

This study aims to evaluate the effectiveness of movement-based gamification in promoting active participation and improving understanding in organic chemistry. Student perceptions were assessed using semi-structured interviews, classroom observations, and pre- and post-activity surveys. These approaches collected both the affective and cognitive components of the learning process. The study involved 30 diploma-level students at UiTM Cawangan Pulau Pinang enrolled in an introductory organic chemistry course. These students had no prior experience with gamified learning techniques, having been previously taught through conventional lectures. This provided a suitable baseline for measuring the relative effectiveness of the gamified intervention compared to conventional teaching methods. The gamified learning activity focused on fundamental topics in organic chemistry. The gamified organic chemistry learning process is visually represented in *Figure 1*. The design of the activity was informed by principles of active and kinesthetic learning, emphasizing physical movement, collaboration, and problem-solving within a competitive yet supportive classroom environment.

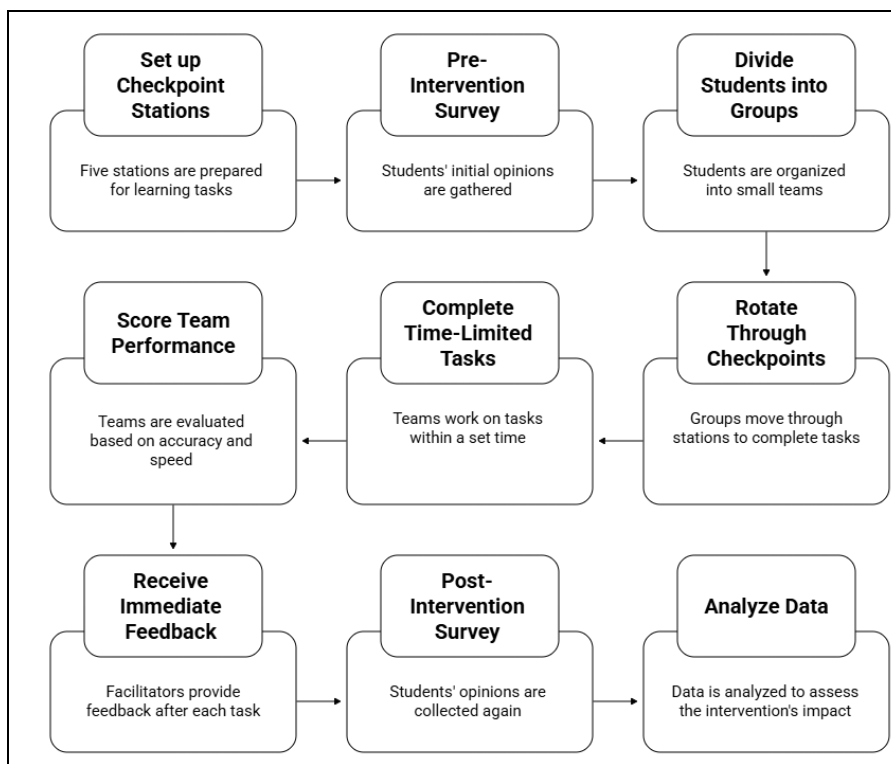


Figure 1. Gamified organic chemistry learning process.

Five checkpoint stations were set up throughout the classroom. Each checkpoint focused on a specific organic chemistry learning task, such as naming compounds, identifying isomers and reactions, identifying the longest chain, and identifying functional groups. To encourage teamwork and collaborative problem-solving, students were divided into small groups of five to six members. Each group rotated among the five checkpoints, spending approximately 10 to 12 minutes at each station before moving to the next. Each checkpoint featured time-limited tasks that required students to apply their conceptual understanding quickly and accurately. Team performance was scored using a points-based system that rewarded accuracy and completion speed, stimulating focus, motivation, and a healthy sense of competition among groups. Facilitators provided immediate feedback after each activity, allowing students to recognize and correct misconceptions in real-time. This feedback mechanism served as an essential component of formative assessment, reinforcing correct understanding and promoting reflective learning. Such feedback loops are supported by gamification theory, which emphasizes the importance of instant reinforcement and visible progress in sustaining learner motivation (Dichev and Dicheva, 2017).

A survey was carried out of students before and after the intervention to gather their opinions. The survey included six indicators aligned with the study's goals: self-assurance in applying concepts, enjoyment of learning, concentration during an activity, recollection of naming rules, teamwork, and motivation to actively participate. Each item was rated using a 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). Observational data on active participation were gathered using a structured participation checklist which tracked student engagement, collaboration, and responsiveness during the gamified sessions. Semi-structured interviews were also conducted with selected participants to gain deeper qualitative insights into their experiences, challenges, and perceived benefits of the activity. All quantitative data

were analyzed descriptively by comparing the percentage of students who agreed or strongly agreed with each indicator before and after the intervention. The percentage improvement was computed to evaluate the effect of the gamified activity. The integration of both numerical trends and qualitative insights strengthened the interpretation of results, ensuring that the findings reflected not only statistical improvements but also meaningful changes in students' engagement and learning attitudes.

Results and Discussion

Improvements in active participation and knowledge retention

To evaluate the impact of movement-based gamification on student learning and engagement, six key indicators were assessed using pre-and post-intervention perception surveys. These indicators captured both cognitive (focus, recall, teamwork) and affective (confidence, enjoyment, motivation) dimensions of learning. Each indicator was rated on a five-point Likert scale, and individual student responses were summed to produce total pre- and post-scores for each indicator. The improvement for each indicator was measured using both the absolute difference in scores and the relative percentage change. As shown in *Table 1*, all six learning indicators demonstrated notable increase following the gamified learning intervention. The highest percentage increase observed in Enjoyment of learning organic chemistry (86%), followed by increases in Motivation to participate actively in class sessions (47%), Focus and on-task behavior during class (52%), and Recall and retention of key naming rules (51%). These findings suggest that the movement-based gamified activity had a positive impact on both cognitive and affective domains of student learning.

Table 1. Comparative pre-and post-session perception scores among diploma-level students (N=30).

Learning indicator	Pre-score	Post-score	Difference	% Change
Confidence in applying organic chemistry concepts	65	98	33	51
Enjoyment of learning organic chemistry	70	130	60	86
Focus and on-task behavior during class	89	135	46	52
Recall and retention of key naming rules	82	124	42	51
Engagement in teamwork and peer discussions	101	147	46	46
Motivation to participate actively in class sessions	87	128	41	47

In general, students showed strong enthusiasm during the activity, which was evident in their survey responses and classroom participation. The significant increase in enjoyment indicates that students perceived the learning experience as fun and interactive, breaking away from the monotony of traditional lecture-based sessions. This sense of enjoyment not only encouraged higher engagement but also contributed to deeper concentration throughout the learning process. Students appeared more motivated to complete tasks, interact with peers, and apply the concepts they had learned. The increase in focus and recall further reflects that gamification helped sustain attention and improve memory retention, which are key indicators of meaningful learning. The improvements in the post-intervention data indicate that the gamified learning approach encouraged students to engage with the content more actively rather than passively receiving information. The physical and competitive nature of the activity may have also contributed to heightened alertness and reduced distraction, as students had to respond quickly to challenges at each checkpoint. This active

participation likely supported the encoding of new information into long-term memory. Moreover, the teamwork element of the exercise appeared to foster communication and cooperation, encouraging participants to share ideas, explain reasoning, and support one another's understanding, key aspects of social constructivist learning.

This is consistent with recent meta-analyses showing gamification's significant impact on learning achievement and motivation, particularly in STEM fields (Rivera and Garden, 2021; Dichev and Dicheva, 2017). These findings are also in agreement with the work of (Zainudin and Zulkipli, 2023), who demonstrated that game elements such as competition, rewards, and immediate feedback can positively influence both intrinsic motivation and knowledge acquisition. Furthermore, the integration of game mechanics appears to align well with self-determination theory, enhancing students' sense of autonomy, competence, and relatedness (Kian et al., 2022; Dichev and Dicheva, 2017). The collaborative and competitive aspects within the gamified checkpoints fostered a sense of healthy competition and teamwork, further contributing to improved learning outcomes (Jagušt et al., 2018). This aligns with previous research highlighting that gamified interventions significantly enhance student motivation, engagement, and understanding of complex STEM concepts (Vang, 2023).

Category-Level Analysis

When indicators were grouped into psychological (confidence, enjoyment, motivation) and behavioral (focus, recall, teamwork) categories, results showed that psychological indicators experienced a greater relative improvement (+60.36%) compared to behavioral indicators (+49.26%), suggesting that the session had a particularly strong effect on students' attitudes and motivation as shown in *Table 2*.

Table 2. Comparative pre-and post-session averages for psychological vs. behavioral indicators.

Category	Pre-score avrage	Post-score average	Percentage change
Psychological	74.00	118.67	60.36%
Behavioral	90.67	135.33	49.26%

Improvements in confidence and enjoyment may stem from the active, collaborative nature of the activity, which reduces the anxiety often associated with organic chemistry learning and fosters a sense of achievement through immediate feedback and peer support. These findings align with research showing that gamification elements, such as challenge-based tasks and rapid feedback, are effective at enhancing learner motivation in STEM contexts (Rayan and Watted, 2024; Vang, 2023; Shoemith et al., 2020). Specifically, the structured challenges within the checkpoints offered opportunities for mastery, promoting a sense of competence that is central to intrinsic motivation. The collaborative learning environment further reinforced positive outcomes by encouraging peer-to-peer instruction and problem-solving, which are known to deepen conceptual understanding and foster a supportive learning community (Vang, 2023). Although the comparatively smaller but still significant gains observed in behavioural indicators may suggest that behavioural modifications, such as enhanced teamwork and sustained focus, typically require more extended practice to become deeply ingrained. This interpretation is supported by studies suggesting that while gamification can stimulate immediate engagement, long-term behavioural improvements depend on repeated exposure and reinforcement over multiple sessions (Rivera and Garden, 2021). The

observed difference between psychological and behavioral outcomes, therefore, reflects the early stage of behavioral adaptation that accompanies motivational growth. With consistent application of gamified learning, it is likely that both domains would continue to strengthen over time.

Observational Findings on Active Participation

Classroom observations further validated the positive survey results, with facilitators consistently observing high levels of engagement, active participation in group-based tasks, and reduced off-task behaviour. Throughout the session, students enthusiastically contributed to discussions, solved naming challenges collaboratively, and demonstrated increased willingness to take intellectual risks, such as volunteering answers without hesitation. Importantly, the time-limited competitive checkpoints encourage sustained attention and quick application of organic chemistry concepts, reducing classroom passivity and encouraging real-time cognitive processing. This observation aligns with studies by King (2023), which affirm that game-based learning strategies can enhance focus, foster collaborative learning, and decrease disengagement in classroom environments. This enhanced engagement likely stemmed from the immediate feedback and competitive elements inherent in the gamified activities, which are known to sustain student interest and promote deeper learning (Hellín et al., 2023). The facilitators also noted that movement-based learning appeared to create a more dynamic classroom atmosphere. Unlike digital-based gamification that often limits students to screen interactions, this non-digital, physical format encouraged interpersonal communication, physical activity, and peer collaboration. Such interactions contributed to a positive learning climate where students were more relaxed, communicative, and responsive. The reduction in passive behavior further suggests that students were mentally and physically invested in their learning, which is essential for developing lasting comprehension in complex topics such as organic chemistry.

Student Perceptions and Feedback

Qualitative feedback obtained through post-session interviews provided further evidence of the gamified activity's positive impact. Students frequently described the gamification format as "more engaging and fun", and many reported feeling "more confident answering nomenclature questions" due to the interactive, low-pressure environment. Students also highlighted that teamwork and healthy competition were motivating factors that encouraged sustained involvement during the session. These reflections align with the ARCS motivational model (Keller, 1987), particularly in activating Attention through engaging mechanics, Relevance by connecting activities to learning goals, Confidence through practice-based reinforcement, and Satisfaction via immediate rewards and feedback loops. The findings are also reinforced by recent research (Alsadoon et al., 2022; Chen and Liang, 2022), suggesting that gamification can substantially elevate student satisfaction and enjoyment, leading to deeper learning experiences. Additionally, the integration of playful competitive elements and social interaction in educational settings promotes higher-order thinking and longer-term knowledge retention, both of which were indirectly reflected in the improved post-session perception scores and observed classroom dynamics (Xu et al., 2022). The students' feedback showed that even learners who were typically less participative in conventional lessons became more involved, indicating that the game-based setting

helped reduce anxiety and increased confidence to contribute. This finding highlights the inclusivity potential of movement-based gamification, which accommodates diverse learning styles and encourages active participation from all students.

Collectively, these findings demonstrate that gamification is not merely an engagement tool but a pedagogically robust strategy that facilitates meaningful learning, promotes active participation, and enhances both motivation and cognitive outcomes in science education, particularly in subjects like organic chemistry that are traditionally perceived as challenging. The integration of movement, competition, and collaboration provided a holistic learning experience that blended enjoyment with conceptual understanding. The consistency between quantitative and qualitative data strengthens the conclusion that movement-based gamification can effectively transform passive learners into active participants in their own learning process.

Pedagogical implications and future directions

The outcomes of this research suggest that movement-based gamification offers a promising instructional approach for science educators aiming to increase engagement and learning effectiveness. The method can be implemented without advanced technology, making it particularly useful in institutions with limited resources. Its emphasis on teamwork, physical activity, and immediate feedback fosters both social and cognitive engagement, addressing common challenges such as student passivity and low motivation in theoretical subjects. Beyond organic chemistry, this approach can be adapted to other STEM areas by designing checkpoints that encourage application of key principles through physical and collaborative tasks. For instance, similar frameworks could be applied to analytical chemistry, biology, or physics to promote active learning through embodied experiences. Educators could also explore hybrid versions that combine digital scoring tools with physical activity for a balanced learning experience. Future studies should consider implementing movement-based gamification over multiple sessions or semesters to evaluate long-term retention, academic performance, and student well-being. Expanding the sample size or comparing results across different institutions may also help generalize findings and refine the design principles for wider application in higher education contexts.

Conclusion

This study conclusively demonstrates that integrating movement-based gamification into organic chemistry education yields substantial improvements in student engagement, motivation, and knowledge retention. The findings highlight that this innovative pedagogical approach significantly boosts students' confidence and enjoyment in learning complex chemical concepts, while simultaneously enhancing their active participation and focus during class. By positively influencing both psychological indicators, such as enjoyment and confidence, and behavioural aspects like teamwork and on-task engagement, this strategy offers multifaceted benefits for STEM education. Ultimately, the results affirm the profound potential of kinesthetic, game-like learning strategies to foster a more dynamic, supportive, and effective learning environment, contributing to holistic student development and improved academic outcomes. Furthermore, the study suggests that movement-based gamification can serve as a practical and low-cost teaching method, especially in resource-limited classrooms. It encourages collaboration, reduces reliance on digital devices, and creates

an engaging environment that supports diverse learning styles. While the results are promising, future research could extend this work by exploring long-term effects on academic achievement and testing its adaptability across different topics and education levels. Overall, movement-based gamification represents an impactful approach for transforming challenging subjects like organic chemistry into enjoyable, meaningful, and interactive learning experiences.

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Conflict of interest

The authors confirm that there is no conflict of interest involve with any parties in this research study.

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