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Gamified Learning Using LoGaLab to Enhance Student Engagement and Conceptual Understanding

Nita Prasyama Azhari[1]✉, Restu Ayu Auliyah[1], Tri Diaz Elvana Rose[1], Laifa Rahmawati[1], Ghoffar Amin[2]

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[1]Universitas Negeri Yogyakarta, Indonesia
[2]University of Otago, New Zealand

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Abstract

The rapid development of educational technology necessitates innovative approaches to enhance student engagement and conceptual understanding in science learning. However, international assessments indicate that Indonesian students' performance remains below the global average, particularly in engagement. This study aimed to examine the effectiveness of gamified learning through Locomotor Game Laboratory (LoGaLab) in improving middle school students' engagement and conceptual understanding of the human locomotor system. A mixed-methods approach with an explanatory sequential design was employed. Quantitative data were collected using learning outcome tests and engagement questionnaires, analyzed through one-sample and paired-sample t-tests. Qualitative data were obtained from classroom observations and semi-structured interviews. The results revealed that student engagement significantly exceeded the theoretical mean ($p < 0.001$), while conceptual understanding improved significantly between pretest and posttest scores ($p < 0.001$). Qualitative findings indicated that LoGaLab enhanced motivation, collaboration, persistence, and active participation through interactive activities. These findings suggest that gamified learning using LoGaLab is an effective instructional strategy for improving student engagement and conceptual understanding in science education. This study contributes to science education by providing novel empirical evidence on how gamification, when structurally integrated with a discovery learning model, can simultaneously optimize both affective engagement and cognitive outcomes within a specific scientific domain.

How to Cite

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✉ Correspondence Author:
E-mail: nitaprasyama.2024@student.uny.ac.id

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INTRODUCTION

The rapid advancement of technology has transformed many aspects of education, providing new opportunities for interactive and innovative learning. However, the potential of technology can only be realized through effective teaching strategies that foster student engagement and improve learning outcomes. International assessments such as the Programme for International Student Assessment (PISA) and the Trends in International Mathematics and Science Study (TIMSS) indicate that Indonesian students' science performance remains below the international average, particularly in cognitive and affective domains (OECD, 2023; Mullis et al., 2020). These findings highlight the need for instructional approaches that go beyond content delivery to develop critical thinking, curiosity, and problem-solving skills. Consequently, improving engagement and learning outcomes in science is crucial, which leads to examining challenges in topics such as the human locomotor system.

Student engagement is one of the crucial factors in determining the success of the learning process in the classroom. Student engagement refers to the level of students' active participation behaviorally, emotionally, and cognitively in the learning activities taking place in the classroom. Research indicates that student engagement is strongly correlated with the quality of the learning process and students' academic achievement. Student engagement is regarded as a key indicator reflecting the extent to which students actively participate in learning activities and demonstrate commitment to the learning goals to be achieved (Li & Xue, 2023). Furthermore, student engagement also serves as a significant predictor of learning success, as actively engaged students tend to exhibit higher learning motivation and better academic performance (Cambay & Paglinawan, 2024). Thus, student engagement not only reflects students' participation during learning but also directly contributes to the quality of learning outcomes achieved by students.

The results of a preliminary study conducted in several schools in the Danurejan subdistrict, Yogyakarta, indicate that student engagement in the learning process is still not optimal and requires further attention. This is evident from the low level of student participation in class discussions, the lack of interaction between students and teachers as well as among students themselves, and the tendency of students to remain passive during the learning process. Several previous studies have also shown that low student engagement can be characterized by students' lack of attention to the subject matter, limited contribution to discussion activities, and low initiative in learning activities (Lasekan et al., 2024). Furthermore, other research indicates that in many learning contexts, students tend to be mere recipients of information passively without demonstrating active involvement in the learning process (Guan, 2024). These conditions suggest that student engagement remains a challenge in the implementation of effective classroom learning.

The low level of student engagement is also evident in science learning at schools, particularly in the topic of the human locomotor system, indicating that engagement in science learning is often low, which negatively impacts participation, motivation, and learning outcomes. In the human locomotor system topic, students frequently perceive the material as abstract and difficult. Field observations and prior studies report that students memorize anatomical terms without understanding functional relationships, show passive attitudes, and participate minimally in discussions (Fredricks et al., 2004; Apriansyah, 2023; Salleh et al., 2021; Luthfyanti et al., 2024). Assessments of learning outcomes further indicate that students often score below the expected standard, reflecting gaps in conceptual understanding and problem-solving skills (Salleh et al., 2021; Luthfyanti et al., 2024). Limited facilities, monotonous teaching methods, and low intrinsic motivation exacerbate these challenges (Cicekci & Sadik, 2019). This underscores the need for innovative strategies to make learning the human locomotor system concrete, meaningful, and capable of improving both engagement and learning outcomes.

Student engagement in learning is influenced by various factors, both those originating from within the students themselves and from the learning environment. Internal factors such as learning motivation, interest in the subject matter, and readiness to learn can affect the level of student engagement during the learning process. On the other hand, external factors such as the learning strategies employed by the teacher, the classroom environment, social interaction in learning, and the use of educational technology also have a significant influence on student engagement (Li & Xue, 2023). Other research also indicates that the effectiveness of learning, social interaction in the classroom, and meaningful learning experiences are important factors that can enhance student engagement in the learning process (Khan et al., 2024). Therefore, learning strategies that are capable of creating an active and interactive learning environment are necessary in order to increase student engagement in the learning process.

Gamification offers a promising approach to address these challenges. By integrating game elements such as challenges, points, and immediate feedback, gamification creates an interactive, enjoyable, and competitive learning environment (Deterding et al., 2011). Prior studies show that gamification enhances intrinsic motivation, fosters active participation, and strengthens conceptual understanding (Hamari et al., 2014; Subhash & Cudney, 2018). However, most research remains general and has not specifically targeted the human locomotor system, leaving a gap for focused gamified interventions. To address this gap, this study introduces Locomotor Game Laboratory (LoGaLab), a gamification-based learning medium developed for teaching the human locomotor system at the middle school level. LoGaLab is expected to enhance engagement behaviorally, cognitively, and emotionally, while simultaneously improving learning outcomes. Despite the growing body of research on gamification in education, limited studies have specifically examined its application in teaching the human locomotor system, particularly within the Indonesian context. Furthermore, there is a lack of empirical evidence integrating gamification with structured learning models to simultaneously enhance both engagement and conceptual understanding. Therefore, this study aims to examine the effectiveness of gamified learning using LoGaLab in enhancing middle school students' engagement and conceptual understanding of the human locomotor system.

METHOD

This study employed an explanatory sequential mixed-methods design, consisting of two phases: quantitative data collection and analysis, followed by qualitative data collection to explain the quantitative findings (Creswell, 2018). The quantitative phase utilized a One-Group Pretest-Posttest Design to measure shifts in engagement and conceptual understanding levels from C1-C5 levels. The subsequent qualitative phase used semi-structured interviews and observations to provide a deeper "why" behind the statistical findings, ensuring a holistic evaluation of the LoGaLab intervention (Acut, 2022; Sivia et al., 2019).

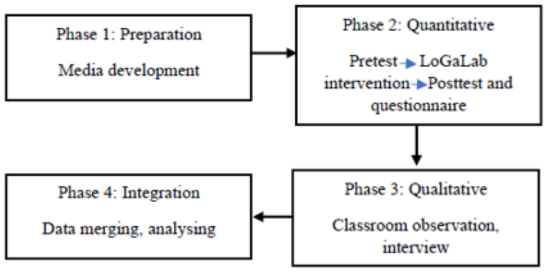

Figure 1. Mixed-Methods Explanatory Sequential Design Study

Respondents

The study involved 21 eighth-grade students from a middle school in Danurejan, Yogyakarta selected using purposive sampling based on curriculum relevance. This technique was chosen to ensure that participants had characteristics and experiences relevant to the research focus, enabling them to provide rich, in-depth information in line with the study objectives (Suen et al., 2024). The sample represents an intact classroom, which serves as the unit of analysis in this classroom-based study. The within-subject design (one-group pretest–posttest) enables the detection of meaningful changes in students' engagement and conceptual understanding within the specific instructional context. The sample size is methodologically appropriate for small scale classroom experiments and pilot instructional interventions where the unit of analysis is a single class (Aslan & Celik, 2022). Heuristic benchmarks in educational research often cite a per-group sample range of 20-30 as defensible for exploratory studies and initial testing of pedagogical innovations (Basekar et al., 2024; Sanchez, 2016). Participants were selected using purposive sampling to align with the eighth-grade curriculum topic of the human locomotor system. However, findings from purposive sampling studies cannot be broadly generalized to the entire population. The generalizability of these findings is restricted to populations or subpopulations that possess characteristics similar to those of the studied sample (Stratton, 2024).

Instruments

The following instruments were developed to triangulate data from multiple perspectives, ensuring a comprehensive evaluation of the LoGaLab intervention:

1. Engagement Assessment Instruments:
   a. Self-Report Questionnaire: A Likert-scale instrument based on the Fredricks et al (2004) framework, measuring behavioral, cognitive, and emotional engagement.

b. Peer Review: An observational tool used during LoGaLab activities to evaluate peer-to-peer collaboration, enthusiasm, and interaction with the gamification features.

The instrument employed in this study underwent initial testing for content validity. The content validity assessment determined the extent to which the instrument's items represented all relevant aspects or domains of the measured construct. Expert lecturers conducted the review (expert judgment). The results, indicated that the student engagement instrument is valid for research purposes, yielding a score of 100% and was classified as very high so it was suitable for use.

2. Qualitative Instruments:

Semi-structured interview: Conducted with selected students from high, medium, and low engagement categories. These interviews aimed to explore the subjective "why" behind student behaviors and their perceptions of the competitive elements of LoGaLab.

3. Conceptual Understanding Instruments:

Pretest-Posttest: A 10 -item assessment designed to measure students' academic gains. To ensure a robust measure of conceptual understanding, the test questions were aligned with the lesson learning objectives across the C1-C5 cognitive levels of Bloom's Taxonomy. Specifically, the items required students not only to identify bones (C1) and explain the mechanism of joints (C2), but also to relate the relationship between bones and muscles during movement (C3), analyze the coordination within the musculoskeletal system (C4), and evaluate the impact of specific disorders or postures on locomotor efficiency (C5). This comprehensive approach provided a more rigorous assessment of their mastery of the locomotor system.

The instrument employed in this study underwent initial testing for content validity. The content validity assessment determined the extent to which the instrument's items represented all relevant aspects or domains of the measured construct. Expert lecturers conducted the review (expert judgment). The results of the study showed that the conceptual understanding instrument was valid for the research purposes, producing a score of 95.83% and was classified as very high so it was suitable for use.

Procedures

The research procedure was systematically divided into three main stages: Preparation, implementation, and evaluation to ensure a logical progression from media development to data conclusions. This sequential structure allows for the systematic alignment of pedagogical theory with practical classroom application.

a. Stage 1: Preparation

In this phase, the researchers developed the gamification-based learning media "LoGaLab", which focused specifically on the human locomotor system. The media was designed to facilitate active learning by allowing students to identify locomotor components, uncover individual bones, and assemble them into a complete system.

b. Stage 2: Implementation

The implementation of LoGaLab was integrated with the Discovery Learning model to provide a structured yet exploratory learning environment. he stages of guided discovery implemented during the learning activities are presented in Table 1.

Table 1. Stages of Guided Discovery Learning in LoGaLab

Guided Discovery Stage	Student Activities in LoGaLab
Stimulation	Students observe images and problems related to the human locomotor system.
Problem Identification	Students identify questions related to bones, muscles, and joints.
Data Collection	Students explore learning materials and Locomotion Pocket Book to gather information.
Data Processing	Students complete tiered challenges (C1-C5) and analyze locomotor structures.
Verification	Students discuss findings with peers and verify answers through quizzes and teacher feedback.
Generalization	Students assemble skeleton models and present conclusions about locomotor system functions.

As shown in Table 1, each stage of Guided Discovery learning model was integrated into LoGaLab's learning activities through structured and interactive tasks. Students were instructed to observe phenomena, identify problems, collect and interpret information, confirm their findings, and make some conclusions collaboratively. This organized learning process allowed students to actively engage in the learning tasks and to develop a deeper conceptual understanding of the human locomotor system.

c. Stage 3: Evaluation

Following the intervention, data were gathered to assess the shifts in students' cognitive and affective states. This phase involved the administration of the posttest and the engagement questionnaire, followed by semi-structured interviews. This evaluative stage allows for the triangulation of quantitative results with qualitative students' voice, providing a comprehensive view of the intervention's effectiveness.

Data Analysis

The data analysis involved two types of data: quantitative and qualitative. Quantitative data collected from the questionnaire and posttest were statistically analyzed using SPSS software.

For student engagement, data were collected using a 4-point Likert scale questionnaire (ranging from 1 = "Strongly Disagree" to 4 = "Strongly Agree"). A one sample t-test was conducted to determine whether the empirical mean score of student engagement was significantly higher than the theoretical mean (midpoint = 2.5). This comparison was used to statistically verify if the students' engagement levels reached a "high" category following the intervention.

Furthermore, a paired sample t-test was used to determine the effect of the LoGaLab Media on students' conceptual understanding by comparing pretest and posttest scores. This test measured the academic gain across the cognitive levels (C1-C5) as defined in the learning objectives.

Qualitative data obtained through classroom observations and student interviews were analyzed using thematic analysis. These findings were used to provide descriptive context and deeper explanations for the quantitative results, thereby integrating both data strands to draw a holistic conclusion (Creswell, 2018).

a. Quantitative Data

The quantitative data analysis in this research includes hypothesis testing.

1) Hypothesis Testing

The hypothesis testing in this research was conducted for student engagement and conceptual understanding.

(a) Student engagement variable hypothesis:

H_0 : Gamification learning using LoGaLab does not have a significant effect on student engagement.

H_1 : Gamification learning using LoGaLab has a significant effect on student engagement.

Criteria for hypothesis testing: H0 is accepted if Sig. $\geq$ 0.05. H0 is rejected if Sig. $<$ 0.05.

(b) Conceptual understanding variable hypothesis:

H_0 : Gamification learning using LoGaLab does not have a significant effect on student conceptual understanding.

H_1 : Gamification learning using LoGaLab has a significant effect on student conceptual understanding.

Criteria for hypothesis testing: H0 is accepted if Sig. $\geq$ 0.05. H0 is rejected if Sig. $<$ 0.05.

b. Qualitative Data

Qualitative data obtained from observations and interviews were examined through thematic analysis. The interview transcripts and observation notes were coded to uncover recurring patterns, themes, and insights that illustrate how and why LoGaLab affects student engagement and conceptual understanding. These identified themes were subsequently utilized to support and contextualize the quantitative findings.

RESULT AND DISCUSSION

This study was conducted to examine whether LoGaLab-based learning has an effect on students' engagement and conceptual understanding. The results show that gamified learning using LoGaLab has a significant impact on student engagement across three main dimensions: behavioral, emotional, and cognitive (Fredricks et al., 2004).

The implementation of LoGaLab-based learning in this study was designed based on the stages of the guided discovery learning model, which emphasizes students' active exploration and concept construction during the learning process. Through these stages, students were encouraged to explore problems, collect information, analyze findings, and construct their own understanding of the human locomotor system.

Student Engagement: Behavioral, Emotional, and Cognitive Dimensions

Student engagement in this study was measured through observation, questionnaires, and peer assessments conducted during the learning process. Results from data analysis with a one-sample t-test using SPSS are shown in Table 2.

Tabel 2. One Sample T-Test

Data collection instrument	Sig (2-tailed)
Questionnaire	*< 0.001*
Peer Review	*< 0.001*

The results of the one-sample t-test indicate that student engagement, as measured through questionnaires and peer review, was statistically significant ($p<0.001$). These findings suggest that the implementation of LoGaLab-based gamified learning can enhance students' engagement during the learning process. To further illustrate students' engagement in LoGaLab-based learning, the mean scores of each engagement dimension are presented in Figure 2.

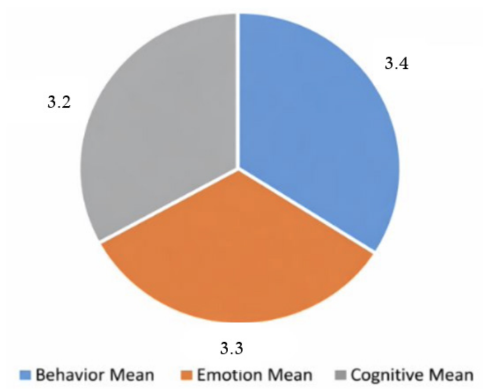

Figure 2. Dimension of Engagement Mean

The findings of this study are consistent with previous research showing that gamification can encourage more active participation, increase enthusiasm, and foster students' tendency to take greater initiative in the learning process (Maulah et al., 2022).

1) Behavioral Engagement

The results obtained can be attributed to learning innovations through the implementation of LoGaLab gamification. These findings are further supported by an analysis of various contributing factors during the learning process and the achievement of student engagement aspects. The following discussion is presented based on the dimensions of student engagement.

The results show that behavioral engagement achieved the highest score compared to the other two dimensions, emotional engagement and cognitive engagement with an average score of 3.28. This indicates that the LoGaLab gamification design is most effective in enhancing overall student participation. These findings are consistent with the study by Rahayuningsih and Susanti (2022), which reported behavioral aspects showed the greatest improvement, reaching 23 %.

From the aspect of compliance with school rules and learning procedures, students were able to follow the teacher's instructions well. During the implementation of LoGaLab, students were required to complete a series of missions in several situations related to the human locomotor system subject. Students were not allowed to proceed to the next stage before completing the mission at the previous stage. Each station contained tiered challenges ranging from C1 to C5, designed to strengthen conceptual understanding. This mechanism helps shape disciplined learning behavior through positive reinforcement, thereby motivating students to comply with rules in order to achieve learning goals (Aini & Husna, 2025).

After all activities were completed, each group assembled a model of the human skeleton and muscles, identified their functions, and presented their result in front of their classmates. Behavioral engagement was reflected in students' activeness, participation in group discussions, and enthusiasm in completing missions to collect points and signatures as proof of task completion. These findings are consistent with Maryana et al. (2024), who stated that point based gamification can enhance students' effort and perseverance in learning. The reward system and immediate feedback implemented in LoGaLab represent one of the core principles of gamification (Aini & Husna, 2025).

In addition, group based missions in LoGaLab encourage students to collaboratively plan strategies, thereby fostering a sense of responsibility and trust among group members (Rahayuningsih & Susanti, 2022). Positive interactions between students and teachers also emerged, further strengthening indicators of behavioral engagement.

2) Emotional Engagement

Emotional involvement ranks second with an average score of 3.3. Students' passion and curiosity during their study of the human locomotor system utilizing LoGaLab led to this outcome. When performing gamification tasks, such identifying bones and muscles through interactive challenges, students expressed satisfaction and engagement. This is in line with Weich et al. (2024), who clarify that affective attachments like enjoyment, contentment, and interest in learning are all part of emotional engagement.

The activity of exploring and assembling the human skeletal and muscular systems provides a challenging yet enjoyable learning experience, which can reduce learning pressure and increase student engagement. Gonzales et al. (2021) reported that assembling anatomical models through interactive tasks can increase engagement and deepen learning. Similarly, the tiered quiz system and point accumulation in LoGaLab foster a sense of satisfaction and pride when students successfully complete each stage. Students engaged in healthy competition to achieve the highest scores and badges, reflecting the values of sportsmanship, confidence, and collaboration (Neerupa et al., 2024).

Emotional engagement in LoGaLab-based learning is often regarded favorably. Throughout the learning process, students experienced motivation, enthusiasm, and happiness. However, more supporting techniques are required because confidence in presenting results is still very low. This result is in line with Fredricks et al. (2004), who confirmed that the existence of positive emotions including joy, enthusiasm, and learning satisfaction is reflected in emotional engagement.

3) Cognitive Engagement

Questionnaire analysis and peer assessment indicate that cognitive engagement also showed a significant increase. Students demonstrate perseverance, curiosity, and mastery of knowledge on the human locomotor system material. The challenge-based design of LoGaLab encourages students to stay focused, as success in one mission becomes motivation to complete the next. This supports the statement by Hamari et al. (2014) that gamification can increase intrinsic motivation and strengthen cognitive engagement.

Learning through observation and inquiry in LoGaLab allows students to experience an authentic discovery process. Students collaboratively identified and analyzed bones, joints, and muscles with the help of the provided Locomotion Pocket Book. Each post presents tiered cognitive challenges, namely C1-C2 for basic identification, C3-C4 for analysis and comparison, and C5 for synthesis and problem-solving. This activity strengthens students' mastery of concepts and critical thinking skills (Purwandari et al., 2024; Rustaman, 2019).

Cognitive engagement is reflected in persistence, meaningful learning, and students' ability to connect new knowledge to real-world contexts (Domínguez et al., 2013). These findings align with constructivist learning theory, which emphasizes active knowledge construction through meaningful experiences. Students build new knowledge based on prior knowledge to solve increasingly complex challenges, reflecting the principles of constructivist learning (Fridrich, 2022). Thus, the implementation of LoGaLab has proven capable of supporting cognitive engagement through exploration, experimentation, and reflection.

Conceptual Understanding as a Cognitive Outcome

The analysis of conceptual understanding revealed a substantial improvement in students' understanding of the human locomotor system. The average pretest and posttest scores are presented in Table 3.

Table 3. Pretest-Posttest Scores

Pretest	Posttest
47.00	78.10

Table 3 shows a substantial increase in students' conceptual understanding of the human locomotor system. The average pretest score was 47.00, indicating that students' initial understanding was relatively low. After participating in LoGaLab-based learning activities, the average posttest score increased to 78.10, demonstrating a notable improvement in students' mastery of the concepts. representing an improvement of 31.10 points. To further determine whether this improvement was statistically significant, a paired sample t-test was conducted. The results of the statistical analysis are presented in Table 4.

Table 4. Paired Sample T-Test Results

Paired Sample T-Test	Sig (2-tailed)
Pretest-Posttest	< 0.001

Based on Table 4, the significance value (Sig. 2-tailed) of < 0.001 is lower than the significance level of 0.05 ($p < 0.05$). This result indicates a statistically significant difference between the pretest and posttest scores. Therefore, it can be concluded that LoGaLab-based learning has a significant effect on improving students' conceptual understanding of the human locomotor system through interactive, sequential, and collaborative learning experiences. These results further confirm that LoGaLab not only enhances students' participation and enthusiasm but also deepens their conceptual understanding through sequential interactive missions and collaborative challenges that stimulate perseverance and meaningful learning.

This increase can be attributed to the interactive and challenge-based structure of LoGaLab, which guides students through sequential tasks according to cognitive levels from C1 (remembering) to C5 (evaluating and creating). This kind of scaffolding encourages deep information processing and concept reconstruction, rather than mere memorization (Rustaman, 2019). Integrating visual, kinesthetic, and problem-solving elements also helps students connect theoretical concepts with real-life contexts, thus promoting meaningful learning (Purwandari et al., 2024).

Additionally, the weak correlation between pretest and posttest scores (r = -0.089; $p = 0.701$) indicates that the improvement in learning outcomes was not solely influenced by prior knowledge, but was primarily a result of the learning intervention. This suggests that even students with low initial abilities were able to achieve significant improvements in conceptual understanding through gamified learning experiences.

Consistent with Fredricks et al. (2004), conceptual understanding represents the cognitive component of student engagement, encompassing persistence, curiosity, and deep comprehension. The LoGaLab learning environment provides meaningful challenges and immediate feedback, motivating students to think critically and apply scientific reasoning. These findings are consistent with Hamari et al. (2014) and Maryana et al. (2024), who confirmed that gamification can enhance cognitive engagement and conceptual understanding by transforming abstract material into interactive and rewarding learning experiences.

This study shows that gamification through LoGaLab significantly affects students' engagement and conceptual understanding in learning the human locomotor system. Increased engagement is evident in the behavioral, emotional, and cognitive dimensions through active participation, enthusiasm, and perseverance of students during the learning process. Meanwhile, improved conceptual understanding is reflected in students' ability to meaningfully construct, apply, and integrate scientific concepts. These findings confirm that LoGaLab-based gamification is an effective learning strategy for simultaneously increasing engagement and deepening conceptual understanding, while also promoting meaningful learning, critical thinking, and collaborative skills in science education.

This study contributes to the existing literature by demonstrating that gamification, when integrated with structured learning models such as discovery learning, can effectively enhance both affective and cognitive learning outcomes. Unlike previous studies that primarily focused on motivation, this research highlights the simultaneous improvement of engagement and conceptual understanding within a specific scientific domain.

Based on these findings, LoGaLab media significantly enhances students' conceptual understanding of the locomotor system. However, this study is limited by its small sample size and single-group design, which may affect generalizability. Future studies should consider a larger sample and a control group to further validate these results.

CONCLUSION

This study concludes that LoGaLab-based gamified learning significantly enhances middle school students' engagement and conceptual understanding of the human locomotor system. The findings demonstrate that integrating gamification with the Discovery Learning model effectively promotes active participation, motivation, collaboration, and meaningful learning while improving students' conceptual mastery through structured, interactive, and challenge-based activities. Beyond confirming the instructional effectiveness of gamification, this study contributes to science education by providing empirical evidence that a gamified learning environment integrated with a structured pedagogical model can simultaneously strengthen both affective engagement and cognitive outcomes within a specific science topic. These findings extend the current body of knowledge on gamification by demonstrating its potential as an effective instructional strategy for fostering comprehensive learning experiences in science education.

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