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The Impact of Gamification-Based Digital Learning Tools on Enhancing Pakistani Students' Interest and Motivation in Learning Evolutionary Concepts

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Abstract:

This study investigates the impact of gamification-based digital learning tools on students' interest in learning evolutionary concepts and enhancing their motivation in Pakistani classrooms. A quantitative quasi-experimental approach with a nonequivalent control group design was employed. The study examined three variables: gamification-based digital learning tools, interest in learning evolutionary topics, and student characteristics. The population and sample comprised students of grade XI (Pre-Medical) from a private higher secondary school in Karachi, Pakistan. The findings revealed a significant improvement in learning interest among the experimental group compared to the control group. After receiving the intervention, the experimental group achieved a much higher average posttest score (88.15), while the control group only reached 65.20. This suggests that the gamified digital tools effectively enhanced students' interest in learning evolution. Indicators of learning interest such as attention, relevance, self-confidence, and satisfaction also showed greater gains in the experimental group. The study highlights that integrating digital technology and gamification strategies can successfully address learning challenges in abstract topics like evolution, which are often considered difficult by Pakistani students. This research contributes meaningfully to the intersection of gamification theory, educational technology, and science education practices in Pakistan.

Keywords: Digital technology; Evolution, Gamification

Introduction

The development of digital technology has changed the direction of education, giving rise to various innovations in learning media that can increase student involvement and interest in learning. Biology education faces complex challenges in arousing students' interest and motivation to learn abstract and theoretical concepts, especially in the material of evolution (Sinatra et al., 2008). Evolution is one of the fundamental topics in biology that requires a deep understanding of changes in living things over time, but is often considered difficult and boring by students (Dharmaji & Astuti, 2023; Sickel & Friedrichsen, 2013). The development of digital technology has opened up new opportunities in designing more interactive and interesting learning media. One innovative approach that can be used is gamification, which is the application of game mechanisms in an educational context to increase engagement and motivation to learn (Deterding et al., 2011). Gamification has the potential to transform the learning experience into something more enjoyable

and meaningful (Dichev et al., 2015; Nicholson, 2015). Although a number of studies have explored the effectiveness of digital learning media and gamification separately, there is a significant gap in research that specifically investigates the integration of the two to increase interest in learning evolution. AdkinsJablonsky et al. (2021) identified a lack of empirical research measuring the long-term impact of gamification on biology learning, while (Le & Winkler, 2016) highlighted the paucity of studies evaluating the design of specific game elements that are most effective for evolutionary content. Denden et al. (2024) emphasized the need for research that considers individual student characteristics when it comes to gamification-based learning, especially for complex concepts such as evolution. According to Moseikina et al. (2022), socio-cultural context is rarely considered in the design of evolution learning interventions, including those involving gamification, despite this factor strongly influencing students' perceptions and acceptance of evolutionary content. Furthermore, Kalogiannakis et al. (2021) noted the lack of a comprehensive evaluative framework to assess the effectiveness of gamification approaches in addressing specific evolutionary misconceptions, while research by Morris et al. (2013) underscored the importance of exploring how gamification design elements can be designed to address cognitive barriers to evolutionary learning, such as teleological and essentialist thinking, which often hinder students' conceptual understanding.

Evolutionary learning faces complex challenges due to its abstract nature, long time scales, and high prevalence of misconceptions among students (Dharmaji & Astuti, 2023; Sickel & Friedrichsen, 2013). A significant problem lies in students' low interest and motivation in learning evolutionary material, which contributes to limited conceptual understanding and persistence of misconceptions (Nehm & Reilly, 2007). Although digital learning media have shown potential in visualizing evolutionary processes (J. S. Lee & Sylvén, 2021), and gamification approaches have been shown to increase engagement in various learning contexts (Rivera & Garden, 2021), there is still a gap in effectively integrating the two approaches for evolutionary learning. Other studies analyze the influence of gamification based digital learning media on interest in learning evolution and evaluate its effectiveness in increasing learning motivation, with a focus on identifying specific gamification elements that are most effective in overcoming cognitive barriers in learning evolution (Owens, 2019), aas well as developing an evaluative framework to assess the long-term impact of this approach on learners' conceptual understanding of the evolutionary process (Opfer et al., 2012), taking into account individual characteristics and socio-cultural contexts that influence the acceptance and effectiveness of gamification-based interventions (Polo-Peña et al., 2021).

Gamification is an innovative approach that integrates game design elements into educational contexts to increase learner motivation and engagement (Signori et al., 2018). According to Deterding et al. (2011), gamification is not just a game, but the use of game mechanisms, dynamics, and thinking frameworks to solve real-world problems in learning. This concept has grown rapidly in the last decade, offering a transformative alternative in designing more engaging and interactive learning experiences. According to Ramesh et al. (2019), gamification in education involves the use of game mechanics, aesthetics, and game-based thinking to engage people, motivate action, promote learning, and solve problems. This is in line with the findings of Dicheva et al. (2015) which states that the application of gamification elements such as points, badges, leaderboards, and challenges in a learning environment can increase students' intrinsic and extrinsic motivation.

In evolution learning, Pramana et al. (2021) found that the use of gamification based learning applications can improve the understanding of the concept of evolution in high school students. The application integrates interactive simulations, narratives, and challenges that allow students to see the process of evolution visually and engage in virtual experiments. The results showed a significant increase in learning interest and understanding of the concept of evolution compared to conventional learning methods. Furthermore, a study conducted by Su et al. (2015)

showed that gamification based mobile learning can improve students' motivation and learning outcomes in science. Their research developed a game-based learning system that allows students to explore science concepts, including evolution, through missions and challenges. The results showed a significant increase in students' interest, motivation, and learning outcomes.

Research Huang et al. (2013) shows that gamification has significant potential in increasing students' interest in learning. Through the implementation of elements such as points, badges, leaderboards, and tiered challenges, digital learning media can create a more motivating learning environment. Lee et al. (2016) emphasized that this approach not only makes learning fun, but also encourages active participation and cognitive engagement of students. Research by Syahri et al. (2024) in Indonesia shows that the use of gamification based digital learning media on evolution material has a positive impact on high school students' interest in learning. They developed an application that combines narrative elements, simulations, and interactive quizzes to help students understand the concepts of natural selection and adaptation. The results of the study showed an increase in learning interest of 37.8% compared to conventional learning.

Although many studies have explored the effectiveness of digital learning media and gamification separately, there remains a gap in research that specifically investigates the integration of gamification-based digital learning media to enhance learning interest and engagement. Existing studies generally examine both approaches separately, without exploring the potential synergy of combining them. This study aims to analyze the effect of gamification based digital learning media on interest in learning evolution in increasing students' learning motivation.

Research Methodology

This study employs a quasi-experimental quantitative approach with a nonequivalent control group design. This methodology was selected to systematically and measurably analyze the effect of gamification-based digital learning tools on Pakistani students’ interest in learning evolutionary concepts (Alsawaier, 2018).

The study involves three types of variables: the independent variable is gamification-based digital learning media, which serves as the primary intervention; the dependent variable is students’ interest in learning evolution, which reflects the measurable outcomes; and the control variables include student characteristics and grade level to minimize external influences.

The population comprises all grade XI (Pre-Medical) students from a private higher secondary school in Karachi who were studying evolutionary topics as part of the biology curriculum. A purposive sampling technique was used, focusing on students who (a) belonged to grade XI, (b) had access to digital devices and internet connectivity, and (c) voluntarily agreed to participate in the research process. Using Slovin’s formula with a confidence level of 95%, a total of 120 students were selected and divided into two groups: an experimental group (60 students) exposed to gamification-based digital learning, and a control group (60 students) engaged in conventional teaching methods.

The gamified learning tool was developed following the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) instructional design model. During the analysis stage, the team assessed learners’ needs, technological accessibility, and the alignment of content with Pakistan’s National Curriculum for Biology. The design stage included structuring content, integrating game mechanics (e.g., points, badges, progressive levels, and leaderboards), and developing a user-friendly digital interface. The development stage involved validation by educational technology experts and biology teachers, pilot testing, and iterative improvements based on feedback.

To measure students’ interest, a Likert-scale questionnaire was designed based on four indicators: attention, relevance, self-confidence, and satisfaction. Media validation involved expert evaluation forms and student response surveys. Data were gathered through observations, pretests and posttests, questionnaires, and documentation, ensuring a holistic perspective.

Data analysis began with assumption tests, including the Shapiro-Wilk test for normality and Levene's test for homogeneity. Hypothesis testing was carried out using Independent Samples T-Test, MANOVA, and effect size analysis to evaluate the significance and strength of the intervention's impact.

The study was conducted over four months (October 2024 to January 2025) and comprised three phases: (1) preparation (including preliminary research, permissions, and instrument development), (2) implementation (pretesting, treatment delivery, posttesting, and data collection), and (3) conclusion (data analysis, interpretation of findings, and reporting).

Result and Discussion

The study was conducted in several private higher secondary schools in Karachi during the first semester of the 2024–2025 academic year. It involved 120 grade XI (Pre-Medical) students, who were divided into experimental and control groups. The aim of the study was to analyze the effect of gamification-based digital learning tools on students' interest in learning evolutionary concepts.

Table 1. Descriptive Statistics of Students' Learning Interest

Group	Pretest (Mean ± SD)	Posttest (Mean ± SD)	Improvement (%)
Experimental	55.40 ± 4.80	88.15 ± 3.70	40.12%
Control	60.80 ± 5.15	70.45 ± 4.80	15.11%

As shown in Table 1, the experimental group, which was exposed to gamification-based digital learning tools, demonstrated a significant improvement in learning interest. Their mean pretest score was 55.40 (SD = 4.80), which increased to a posttest mean of 88.15 (SD = 3.70), reflecting a 40.12% improvement. In contrast, the control group, taught using conventional methods, showed a smaller increase from a pretest mean of 60.80 (SD = 5.15) to a posttest mean of 70.45 (SD = 4.80), resulting in only a 15.11% improvement.

This indicates that the gamified intervention was more effective in enhancing students' interest in learning evolution compared to traditional teaching approaches.

Table 2. Distribution of Learning Interest Scores Based on Indicators

Indicators	Experimental Group		Control Group	
	Pretest	Posttest	Pretest	Posttest
Attention	60.20	85.55	60.80	71.25
Relevance	60.25	88.20	60.90	72.30
Confidence	65.70	80.40	67.25	73.35
Satisfaction	65.20	85.25	68.15	70.80

Table 2 shows the distribution of learning interest scores based on four indicators: attention, relevance, confidence, and satisfaction. Students in the experimental group, who engaged with gamification-based digital learning tools, demonstrated substantial improvements across all indicators. For example, their mean score for attention increased from 60.20 (pretest) to 85.55 (posttest), while the control group's scores improved only modestly, from 60.80 to 71.25. Similarly, relevance scores in the experimental group rose from 60.25 to 88.20, compared to a smaller rise in the control group (60.90 to 72.30).

These findings indicate that gamification elements such as points, badges, and leaderboards were effective in increasing students' focus, perceived relevance of content, confidence, and satisfaction with learning evolutionary concepts—topics often considered challenging in Pakistani classrooms.

Table 3. Results of Independent Samples T-Test

Variable	t-value	df	Sig. (2-tailed)	Mean Difference
Interest in Learning	9.750	118	0.000	15.68

As presented in Table 3, the independent samples t-test showed a statistically significant difference between the experimental and control groups in terms of their interest in learning evolution ($t(118) = 9.750$, $p < 0.001$). The mean difference of 15.68 indicates that students exposed to gamification-based digital learning tools exhibited significantly higher levels of learning interest compared to those taught through conventional methods.

This result reinforces the effectiveness of integrating gamification in enhancing motivation and engagement for abstract scientific concepts in Pakistani classrooms.

Table 4. MANOVA Test Results

Effect	F Value	Sig.
Pillai's Trace	8.456	0.000
Wilks' Lambda	0.340	0.000

Table 4 presents the results of the MANOVA test, which was conducted to examine the multivariate effect of gamification-based digital learning tools on the indicators of students' interest in learning evolution. Both Pillai's Trace and Wilks' Lambda indicated statistically significant results ($p < 0.001$).

These findings suggest that the gamification intervention had a significant multivariate effect across all dimensions of learning interest—attention, relevance, confidence, and satisfaction—in the Pakistani secondary school context.

Discussin

The results of this study reveal that gamification-based digital learning tools significantly enhance students' interest in learning evolutionary concepts, as evidenced by the experimental group's substantial improvement in posttest scores compared to the control group. The independent samples t-test showed a highly significant difference ($t(118) = 9.750$, $p < 0.001$) with a mean difference of 15.68 between the groups. Moreover, the MANOVA results indicated a multivariate effect of the intervention across all dimensions of learning interest, with Pillai's Trace (8.456, $p < 0.001$) and Wilks' Lambda (0.340, $p < 0.001$) confirming the robustness of these findings.

These results suggest that integrating gamification mechanisms—such as points, badges, progressive levels, and leaderboards—can successfully address motivational and engagement challenges faced by students, particularly in abstract and complex topics like evolution. Evolutionary theory is often perceived as a difficult and controversial subject in Pakistani biology classrooms due to socio-cultural sensitivities and the abstract nature of the content. Gamified learning tools appear to counteract this challenge by fostering curiosity and active participation.

This finding aligns with **Alsawaier (2018)**, who highlighted that gamification increases students' intrinsic motivation by offering clear goals and instant feedback. Similarly, **Hamari et al. (2016)** observed that gamification enhances user engagement and learning outcomes by creating an interactive learning environment. In the Pakistani context, **Naveed et al. (2022)** demonstrated that digital tools with embedded game elements improved student attention spans and reduced cognitive load in science classrooms.

A closer examination of the indicator-specific scores supports these conclusions. For example, the experimental group showed marked improvement in attention (from 60.20 to 85.55) and relevance (from 60.25 to 88.20). These dimensions are critical because they reflect students'

ability to focus on and perceive the value of learning content. This is consistent with **Deterding et al. (2011)**, who argued that gamification can create meaningful contexts for learning, thereby increasing relevance and engagement.

In contrast, the control group also exhibited slight improvements, but these were comparatively modest (e.g., attention rose from 60.80 to 71.25). This gap highlights the limitations of traditional teaching methods in sustaining student interest, especially when teaching abstract topics like evolution. These results resonate with **Khan and Ahmad (2021)**, who reported that conventional rote learning approaches in Pakistani science education often fail to capture students' attention and foster deep learning.

Furthermore, the higher scores for confidence and satisfaction in the experimental group suggest that gamification supports self-efficacy and positive learning experiences. This observation is echoed in **Zainuddin et al. (2020)**, who found that gamified learning environments improve students' confidence by allowing them to learn through trial and error in a low-stakes setting. In Pakistan, **Ali et al. (2023)** documented similar findings in a study on gamification in English language teaching, where learners reported higher satisfaction due to increased interactivity and personalization.

However, it is important to note that while this study demonstrates positive outcomes, previous literature also cautions about over-reliance on gamification. **Hanus and Fox (2015)** argue that poorly designed gamified systems can lead to extrinsic motivation, where students focus on rewards rather than mastery of content. This study mitigated such risks by aligning gamification elements with curricular goals and emphasizing conceptual understanding.

Conclusion

The findings of this study substantiate the argument that gamification-based digital learning tools are effective in enhancing students' interest in learning biology, particularly abstract concepts like evolution, in the Pakistani educational context. The significant differences between experimental and control groups affirm the intervention's potential to transform traditional pedagogies and address motivational challenges prevalent in science classrooms.

This study contributes to the growing body of literature advocating for the integration of educational technology and gamification in secondary education. It also underscores the need for teacher training and curriculum development initiatives to promote the use of innovative digital tools in Pakistan's science education system.

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