

DIGITAL TRANSFORMATION OF GAMIFICATION-BASED BIOLOGY EDUCATION

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Abstract: The digital transformation of education signifies a fundamental shift that extends beyond the mere conversion of traditional instructional materials into digital formats. One manifestation of this shift is the development of gamified learning media, particularly within biology education. This study explores the potential of gamified digital environments to foster cognitive engagement, deepen conceptual understanding, and enhance learner motivation. Employing a research and development approach guided by the ADDIE model comprising analysis, design, development, implementation, and evaluation the media was created using the Genially platform. Implementation outcomes indicated that 64.4% of users deemed the media suitable for use, 61.5% positively rated its interactivity and user interface, and 62.3% affirmed its alignment with students' proficiency levels and intended learning outcomes. Accordingly, the gamified learning media contributes to the diversification of biology instructional tools, promoting meaningful learning experiences and increased student engagement.

Keywords: Digital Transformation, Gamification, Biology Learning Media

Abstrak: Transformasi digital dalam pendidikan menandai pergeseran mendasar yang melampaui sekadar mengubah materi pembelajaran tradisional ke dalam format digital. Salah satu wujud dari pergeseran ini adalah pengembangan media pembelajaran berbasis gamifikasi, khususnya dalam pendidikan biologi. Penelitian ini mengkaji potensi lingkungan pembelajaran digital yang digamifikasi dalam meningkatkan keterlibatan kognitif, pemahaman konseptual, dan motivasi belajar peserta didik. Dengan menggunakan pendekatan penelitian dan pengembangan yang berlandaskan model ADDIE meliputi tahap analisis, desain, pengembangan, implementasi, dan evaluasi media ini dikembangkan melalui platform Genially. Hasil implementasi menunjukkan bahwa 64,4% pengguna menilai media ini layak digunakan, 61,5% memberikan penilaian positif terhadap interaktivitas dan antarmukanya, serta 62,3% menyatakan kesesuaian media dengan tingkat kemampuan peserta didik dan capaian pembelajaran yang diharapkan. Dengan demikian, media pembelajaran berbasis gamifikasi ini berkontribusi dalam memperkaya ragam alat pembelajaran biologi, mendorong pengalaman belajar yang bermakna, dan meningkatkan keterlibatan siswa.

Kata Kunci: Transformasi Digital, Gamifikasi, Media Pembelajaran Biologi

INTRODUCTION

The rapid advancement of digital technologies has catalyzed a paradigm shift in educational practices, necessitating the reconfiguration of instructional models to align with the demands of 21st century learners (Parveen & Ramzan, 2024; Kalyani, 2024; Zou, et al, 2025). Within this evolving landscape, biology education faces unique challenges due to its inherently abstract concepts, dynamic systems, and interdisciplinary nature. Traditional pedagogical approaches, which often rely on didactic delivery and static materials, are increasingly insufficient in fostering deep conceptual understanding, learner engagement, and scientific literacy (Lampropoulos & Sidiropoulos, 2024).

Digital transformation in education signifies a profound shift that goes well beyond the superficial act of converting traditional learning materials into digital formats. It involves a deliberate and strategic integration of technological tools, platforms, and methodologies into the fabric of teaching and learning processes. This transformation is not merely about replacing paper with screens or lectures with videos; rather, it is about rethinking how technology can be harnessed to elevate pedagogical effectiveness by enabling more interactive, adaptive, and data-informed instruction. It also seeks to empower learners with greater autonomy, allowing them to take ownership of their educational journeys through personalized pathways, self-paced modules, and access to diverse resources. Furthermore, digital transformation emphasizes contextual relevance ensuring that technological interventions are responsive to the cultural, social, and economic realities of learners, thereby making education more inclusive, equitable, and meaningful (Mhlanga, 2024; Joseph, et al, 2024).

In this context of educational innovation, gamification has increasingly gained recognition as a compelling and forward-thinking instructional design strategy, offering educators a dynamic approach to reimagining the learning experience (Lampropoulos & Kinshuk, 2024; Jun & Lucas, 2025). Rather than being confined to entertainment or leisure, gamification involves the purposeful integration of game-based elements such as points, levels, badges, challenges, leaderboards, and real-time feedback mechanisms into traditionally non-game environments like classrooms, online learning platforms, and professional training modules. These elements are strategically employed not for superficial engagement, but to activate deeper psychological drivers that foster intrinsic motivation, encourage persistence, and promote meaningful learner interaction. By transforming routine educational tasks into interactive and rewarding experiences, gamification aims to sustain learners' attention, stimulate curiosity, and create a sense of accomplishment that fuels continued participation. Moreover, when thoughtfully designed, gamified learning environments can support differentiated instruction, facilitate formative assessment, and nurture collaborative learning communities, ultimately contributing to more personalized, inclusive, and effective educational outcomes.

In the context of biology learning, gamification offers a multifaceted approach to instructional innovation. It enables the simulation of biological processes, visualization of complex systems, and facilitation of inquiry-based learning through interactive digital environments (Fathi Najafi, et al, 2025). Such affordances are congruent with the principles of educational technology, which advocate for learner-centered, adaptive, and competency-driven pedagogical frameworks.

This study aims to examine the role of gamification within the broader scope of digital transformation in biology education. Specifically, it investigates how gamified digital learning environments can enhance cognitive engagement, conceptual mastery, and learner motivation. By situating the inquiry within the theoretical foundations of educational technology, the research endeavors to contribute to the development of transformative instructional models that are pedagogically sound, technologically enriched, and responsive to the evolving needs of contemporary biology learners.

METHOD

This study employs the Research and Development (R&D) methodology, which refers to a structured and purposeful approach to designing, executing, and applying research in order to address practical challenges within development contexts (Laws et al., 2013). The process encompasses need identification, evidence generation, stakeholder engagement, and strategic dissemination of findings to inform and transform educational practices, policy frameworks, and broader social outcomes. To guide the development of gamification-based digital media in biology education, the study integrates the ADDIE model (Mayer, 2009) a well-established instructional design framework consisting of five phases: Analysis, Design, Development, Implementation, and Evaluation. Renowned for its iterative and learner-centered orientation, the ADDIE model facilitates systematic innovation in educational technology and ensures that media products are pedagogically sound and contextually relevant.

RESULT AND DISCUSSION

In the initial stage of development, a comprehensive needs analysis was conducted focusing on curriculum mapping. This process ensured that the gamification strategy being designed is coherently aligned with the essential subject matter which is biology and mostly focused on senior high school material such as human circulatory system, core competencies, and learning objectives outlined in the national curriculum standards integrated to the deep learning approach as personalized learning pathways (Naseer, et al, 2024). Concurrently, an evaluative review was carried out to assess the readiness and suitability of existing digital platforms, technological infrastructure, and user accessibility, all of which are critical to supporting an effective gamified learning environment.

The development of biology-based games was systematically embedded within the instructional strategy, ensuring that key gamification elements such as points, levels, badges, and feedback loops were meaningfully aligned with the biology curriculum content. To support this integration, visual planning tools including storyboards and flowcharts were constructed to map out the learning sequences, interactive features, and user navigation pathways. This design phase was followed by the selection of the most suitable digital platform to host the gamified content, with Genially.com chosen for its interactive capabilities and user-friendly interface (Aldalur, 2025; Núñez-Naranjo, et al, 2024; Lopes, et al, 2024). The integration of gamification into biology instruction was not only intended to enhance student engagement, but also to foster deeper conceptual understanding through experiential learning. By embedding game mechanics within scientifically accurate content, learners are encouraged to actively explore biological processes, apply critical thinking, and receive immediate feedback on their progress. This approach supports differentiated learning pathways, allowing students to navigate content at their own pace while maintaining motivation through achievement-based incentives. Furthermore, the use of Genially.com as the delivery platform enables seamless incorporation of multimedia elements such as animations, quizzes, and clickable diagrams which are particularly effective in visualizing complex biological concepts and promoting interactive, inquiry-based learning experiences.

In this development phase, the prototype was meticulously crafted as a digital learning medium that integrates three key components: gamification features, structured biology content, and interactive learning tasks. The gamification elements such as points, levels, badges, and feedback mechanisms were embedded not merely for engagement, but to reinforce conceptual understanding and motivate learner progression. The biology material was curated to align with national curriculum standards, ensuring pedagogical relevance and coherence. Interactive tasks were designed to stimulate critical thinking, promote active participation, and accommodate diverse learning styles. Once the prototype was assembled using genially platform, the process advanced to a technical testing stage. This involved cross-platform functionality checks, including responsiveness on various devices (e.g., smartphones, tablets, laptops), browser compatibility, and accessibility features. The goal was to ensure that the media operates smoothly, remains intuitive for users, and is inclusive for learners with different technological access and needs. Below is the developed gamified-media.

During the implementation phase, the prototype underwent practical testing through its deployment in selected biology classrooms, allowing for direct interaction between students, educators, and the gamified digital media. This stage enabled observation of user engagement and instructional dynamics in real-time. Following the classroom trials, data collection was conducted by distributing a closed-ended survey to participants, aimed at capturing their perceptions, experiences, and evaluative feedback regarding the effectiveness and appeal of the developed educational games.

Findings from the survey reveal that 64.4% of participants perceive the gamified learning media as suitably appropriate for educational implementation. Furthermore, 61.5% positively evaluated its interactivity and user interface, citing an error-free experience during the trial phase. In addition, 62.3% of respondents confirmed that the instructional content developed is well-

aligned with students' competency levels and intended learning outcomes. Therefore, the gamified learning media contributes meaningfully to enhancing learning activities (Syafitri & Sujannah, 2024; Barrera & Maier, 2024), increasing student engagement (Rahayu, et al, 2024), and diversifying instructional media (Hernández, et al, 2024).

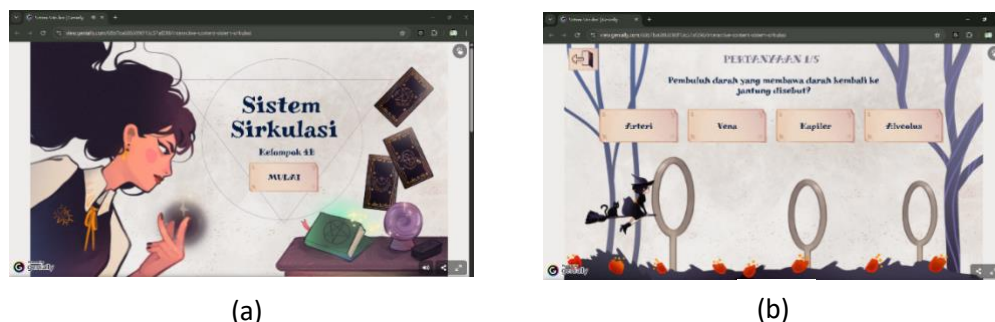


Figure 1. (a) Homepage of Biology Games, and (b) Part of Gamified-Quiz . (Source: a developed gamified-media).

The evaluation process was carried out through reflective analysis and systematic synthesis of research findings. This approach aimed to generate insights that would guide future refinements of the gamified media, support its potential for broader implementation, and ensure its adaptability to diverse educational contexts. In addition, the evaluation considered both pedagogical effectiveness and user experience, drawing on feedback from students and educators to identify strengths, limitations, and areas for improvement. This iterative reflection not only informed technical adjustments and content enhancement, but also contributed to the formulation of recommendations for scaling the media across different biology topics and learning environments.

CONCLUSION

The development of gamified learning media in biology education represents an ongoing process of digital transformation. Its effectiveness in enhancing learning activities and diversifying instructional media has been demonstrated. Consequently, similar research and development initiatives may be extended to other areas of biological content.

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