

# Gaming for the Education of Biology in High Schools

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Game-based learning refers to an educational approach where games (digital or analogue) are used in order to engage students in interactive and immersive experiences designed to teach specific concepts, skills or subjects. Gamification refers to the application of game design elements, such as point systems, rewards, narratives, and competition, to non-game contexts. Game elements, mechanics and structures, when incorporated into the learning process, can enhance student understanding and increase engagement, motivation and retention of educational content. Teaching Biology can present challenges mainly due to the complexity of the subject matter, the different scales of biological organisation, and because it often includes challenging and counterintuitive concepts that may contradict students' preconceived notions. Integrating gaming into the high school Biology curriculum not only tackles the challenges of teaching complex concepts but can also promote student engagement. Customising gaming experiences to Biology intricacies enhances critical thinking and creates a dynamic learning environment tailored to the demands of high school biological education. This entry explores the integration of gaming and gamification in high school Biology education to overcome challenges in sustaining student interest. Additionally, the article highlights the diverse applications of games in education, showcasing their versatility in enriching the educational process. Future research should evaluate specific games, explore design principles, and consider challenges associated with implementation. In conclusion, using games in Biology education promises to enhance engagement, promote active learning, and deepen understanding, contributing to narrowing the gap in biological literacy.

Keywords: gamification in biology ; board games ; serious games ; gamified education

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Teacher-centred methods of teaching Biology in high schools often face challenges in capturing and sustaining students' interest. Gaming and gamification present an opportunity to address this issue by tapping into the natural affinity that students have for interactive and enjoyable experiences. Incorporating gaming into the high school Biology curriculum offers a transformative approach by addressing the unique challenges of teaching complex biological concepts and promoting student engagement. By tailoring gaming experiences to the intricacies of Biology, educators can enhance student engagement, promote critical thinking, and provide a dynamic learning environment that aligns with the specific demands of biological education in high schools.

The term "gamification" is primarily used to describe the application of game elements and mechanisms in non-game environments, with the ultimate goal of enhancing processes and improving the experience of the involved parties <sup>[1]</sup>. A second definition of gamification suggests that it is the use of the logic and dynamics of games to solve problems and increase the audience's dependence on them <sup>[2]</sup>. This practice utilises features that make a game enjoyable to enhance user engagement, such as points, badges, tracks, difficulty levels, leaderboards, etc. <sup>[3]</sup>.

It should be noted that gamification first gained popularity in fields other than education <sup>[4]</sup>, as applications have been developed in various fields, such as entrepreneurship, aiming to improve personnel performance or increase and retain customer loyalty (e.g., point collection systems from purchases, visits, and similar rewards). It is also applied in the health sector as motivation for improving physical fitness (e.g., personal trainer applications, pedometers) and as a means for collecting experimental data by research entities, among many other areas of our daily lives.

Students respond better to interactive learning environments <sup>[5][6][7][8]</sup>, and the need to shift from the teacher-centred model to a more learner-centred, collaborative model is becoming evident. Games expose children to learning situations that often involve activities slightly beyond their current skill levels, making them valuable in early childhood and later education <sup>[9]</sup>. The use of games as a medium for learning is not a new idea, as games, regardless of difficulty or complexity, with or without technology, can aid the learning process. Through games, cause-and-effect relationships can be taught, and what is learned through games tends to be better retained by students due to the interactive nature of the learning experience <sup>[10]</sup>.

As the use of digital (mainly) games by children and adolescents outside the school context continues to increase, researchers, educators, and programmers have developed a particular interest in these games. International literature

increasingly refers to the use and effectiveness of games in the educational process, and various applications have been developed to facilitate their use by educators (e.g., Kahoot!, Edmodo, quizizz, wordwall, helpfulgames, learning Apps, and many more). Studies show that gamification can improve the motivation and performance of students in a variety of learning environments <sup>[11][12][13][14]</sup>.

However, most modern research tends to overlook how individual student characteristics influence the impact of game elements on their engagement and involvement in learning. Research, nevertheless, indicates that the perception and response to game elements vary among students, suggesting a need for personalised gamification <sup>[14]</sup>.

Biology as a subject lends itself to the creation of educational games, and there are numerous gamification tools that can be applied in its teaching. Gamification in Biology can capture students' interest, not only in urgent remote education but also in face-to-face teaching, especially as in some cases (e.g., in Greece) it has been downgraded to a single-hour class in secondary education, leading to a loss of connection between the teacher, students, and the subject. Gamification tools provide the opportunity for further engagement of students without imposing the burden of "homework".

The characterisation of COVID-19 as a pandemic on 11 March 2020 <sup>[15]</sup> placed all countries in a state of emergency. Since then, the pandemic has affected, among other things, the operation of educational institutions worldwide, as educators and learners are required to adapt to new challenges. The model primarily utilised is that of "emergency remote learning" (ERL). However, this model can easily devolve into a low-interaction model between educators and students, where knowledge is simply transmitted from the transmitter (educator) to the receiver (learner), downgrading the quality and effectiveness of the educational process.

Gamification can play a significant role in upgrading emergency distance education by providing tools to educators to capture students' interest and actively engage them in learning. The lesson becomes more enjoyable, the students' experience improves, and their commitment may increase <sup>[16]</sup>.

Remote learning emerged out of necessity and caught a significant part of the educational community unprepared. However, integrating technology into the educational process will help upgrade it, and it is certain that many of the methods and techniques employed out of necessity will remain even after the pandemic. The educational process and our understanding of pedagogy are evolving.

The game exposes the child to a learning situation, as it often involves activities that are slightly beyond the skills the child has already acquired. For this reason, games have been adopted early on in preschool and later education <sup>[9]</sup>. The use of games as a means of learning is not a new idea. Regardless of the level of difficulty or complexity and whether or not technology is involved, games can aid the learning process. Through games, causal relationships can be taught, and what is learned through games tends to be better retained by students, mainly due to the interactive nature of the learning experience <sup>[10]</sup>.

As the use of digital (mainly) games by children and adolescents outside the school context continues to increase, researchers, educators, and programmers have developed a particular interest in these games. International literature increasingly refers to the use and effectiveness of games in the educational process <sup>[17][18][19][20][21][22][23]</sup>.

Extensive academic research (e.g., <sup>[6][10][17][19][24][25][26]</sup>) has minimised most of the doubts related to the use of video games as learning tools. However, this does not mean in any way that conclusions can be drawn and generalised about all games, all fields, and all learners based on research on the effectiveness of one game in one learning area for one group of learners <sup>[10][27]</sup>.

Through the exploration of the educational value of engaging with science through computer technology, it has been found that knowledge acquisition is better supported as science becomes accessible, thinking becomes visible, students can learn from each other, and autonomous learning is promoted <sup>[18][28]</sup>.

These games could transform not only the way we learn but also individuals at various levels. In the technical report by Hays <sup>[29]</sup> ways in which games can be used in education are mentioned:

- \* Assessment of Existing Cognitive Levels
- \* Performance Measurement on Various Criteria
- \* Assistance in Evaluating Educational Approaches and Programs

- \* Providing Educational Information on Specific Knowledge and Skills
- \* Aiding in Changing Attitudes/Perceptions
- \* Serving as Pre-Organisers for Other Forms of Education
- \* Replacing Other Forms of Teaching to Convey Facts, Teach Skills, and Provide Knowledge
- \* Serving as Training/Practice Mediums, Problem Solving/Exercise
- \* Aiding in the Integration and Retention of Knowledge and Skills
- \* Representing the Dynamics or Abstract Concepts of a Cognitive Object

These diverse applications highlight the versatility of games in the educational domain, demonstrating their potential to enhance learning experiences and outcomes in various ways.

This entry paper delves into the potential of incorporating gaming elements into high school Biology education in order to capture and retain student interest in complex biological concepts. This paper explores how well-designed educational games can address this challenge. By examining the unique strengths of game-based learning and its effectiveness in promoting knowledge acquisition, engagement, and critical thinking skills, this paper aims to provide a compelling argument for integrating gaming into the high school Biology curriculum. We will explore various game types, analyse their suitability for different learning objectives, and discuss practical considerations for teachers seeking to implement game-based learning strategies in their classrooms.

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## References

1. Deterding, S.; Dixon, D.; Khaled, R.; Nacke, L. From game design elements to gamefulness: Defining 'gamification'. In Proceedings of the International Academic MindTrek Conference: Envisioning Future Media Environments, MindTrek, Tampere, Finland, 28–30 September 2011; pp. 9–15.
2. Zichermann, G.; Cunningham, C. Gamification by Design: Implementing Game Mechanics in Web and Mobile Apps; O'Reilly Media, Inc.: Sebastopol, CA, USA, 2011.
3. Nah, F.; Zeng, Q.; Telaprolu, V.R.; Ayyappa, A.P.; Eschenbrenner, B. Gamification of Education: A Review of Literature —HCI in Business. *HCI Bus.* 2014, 8527, 401–409.
4. Hulse, N. Defining Gamification; Emerald Publishing Limited: Leeds, UK, 2019.
5. Hong, J.C.; Cheng, C.L.; Hwang, M.Y.; Lee, C.K.; Chang, H.Y. Assessing the educational values of digital games. *J. Comput. Assist. Learn.* 2009, 25, 423–437.
6. Prensky, M. Fun, Play and Games: What Makes Games Engaging. In *Digital Game-Based Learning*; McGraw Hill: New York, NY, USA, 2001; pp. 05.1–05.31.
7. Prensky, M. Engage me or enrage me. *Educ. Rev.* 2005, 40, 61–64. Available online: [https://www.marcprensky.com/writing/Prensky-Engage\\_Me\\_or\\_Enrage\\_Me.pdf](https://www.marcprensky.com/writing/Prensky-Engage_Me_or_Enrage_Me.pdf) (accessed on 31 March 2024).
8. Rosier, R.L. Students' Perceptions of Interactive Biology Instruction. *Am. Biol. Teach.* 2017, 79, 621–625.
9. Vygotsky, L.S. Play and Its Role in the Mental Development of the Child. *Sov. Psychol.* 1967, 5, 6–18.
10. Annetta, L.A.; Minogue, J.; Holmes, S.Y.; Cheng, M.T. Investigating the impact of video games on high school students' engagement and learning about genetics. *Comput. Educ.* 2009, 53, 74–85.
11. Borrás-Gene, O.; Martínez-núñez, M.; Fidalgo-Blanco, Á. New Challenges for the motivation and learning in engineering education using gamification in MOOC. *Int. J. Eng. Educ.* 2016, 32, 501–512.
12. González-González, C.; Blanco-Izquierdo, F. Designing social videogames for educational uses. *Comput. Educ.* 2012, 58, 250–262.
13. Jia, Y.; Xu, B.; Karanam, Y.; Voids, S. Personality, targeted gamification: A survey study on personality traits and motivational affordances. In Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems, San Jose, CA, USA, 7–12 May 2016; Association for Computing Machinery (ACM): New York, NY, USA; pp. 2001–2013.
14. Lopez, C.E.; Tucker, C. Implementing gamification in engineering bridge programs: A case study exploring the use of the Kahoot! application. In Proceedings of the 2019 ASEE Zone I Conference & Workshop, Niagara Falls, NY, USA,

15. Tedros, A.G. WHO Director-General's Opening Remarks at the Media Briefing on COVID-19—11 March 2020. In WHO Director General's Speeches; WHO: Geneva, Switzerland, 2020; p. 4. Available online: <https://www.who.int/dg/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19--11-march-2020> (accessed on 31 March 2024).
16. Λαντζούνη, Μ.; Δημοπούλου, Α.; Πουλόπουλος, Β.; Γουάλλες, Μ. Παιχνιδοποίηση και εκπαιδευτικά παιχνίδια στη διδασκαλία της Βιολογίας την περίοδο της πανδημίας COVID 19. *Διδασκαλία Των Φυσικών Επιστημών Έρευνα Πράξη* 2021, 81, 167–195.
17. Chang, C.Y.; Hwang, G.J. Trends in digital game-based learning in the mobile era: A systematic review of journal publications from 2007 to 2016. *Int. J. Mob. Learn. Organ.* 2019, 13, 68–90.
18. Hussein, M.H.; Ow, S.H.; Cheong, L.S.; Thong, M.K.; Ebrahim, N.A. Effects of Digital Game-Based Learning on Elementary Science Learning: A Systematic Review. *IEEE Access* 2019, 7, 62465–62478.
19. Ronimus, M.; Eklund, K.; Pesu, L.; Lyytinen, H. Supporting struggling readers with digital game-based learning. *Educ. Technol. Res. Dev.* 2019, 67, 639–663.
20. Theodoropoulos, A. Framework for the effective implementation of alternative teaching methods for Informatics. Ph.D. Thesis, University of the Peloponnese, Tripoli, Greece, 2017.
21. Li, M.-C.; Tsai, C.-C. Game-Based Learning in Science Education: A Review of Relevant Research. *J. Sci. Educ. Technol.* 2013, 22, 877–898.
22. Barko, T.; Sadler, T.D. Learning outcomes associated with classroom implementation of a biotechnology-themed video game. *Am. Biol. Teach.* 2013, 75, 29–33.
23. Sung, H.Y.; Hwang, G.J. A collaborative game-based learning approach to improving students' learning performance in science courses. *Comput. Educ.* 2013, 63, 43–51.
24. Liao, C.W.; Chen, C.H.; Shih, S.J. The interactivity of video and collaboration for learning achievement, intrinsic motivation, cognitive load, and behavior patterns in a digital game-based learning environment. *Comput. Educ.* 2019, 133, 43–55.
25. Annetta, L.A.; Cheng, M.T.; Holmes, S. Assessing twenty-first century skills through a teacher created video game for high school biology students. *Res. Sci. Technol. Educ.* 2010, 28, 101–114.
26. Squire, K.; Jenkins, H. Harnessing the power of games in education. *Insight* 2003, 3, 5–33.
27. Borsos, E. The gamification of elementary school biology: A case study on increasing understanding of plants. *J. Biol. Educ.* 2019, 53, 492–505.
28. Komaraju, M.; Karau, S.J.; Schmeck, R.R. Role of the Big Five personality traits in predicting college students' academic motivation and achievement. *Learn. Individ. Differ.* 2009, 19, 47–52.
29. Hays, R.T. The Effectiveness of Instructional Games: A Literature Review and Discussion (U); Technical Report; Naval Air Warfare Center Training Systems Division: Orlando, FL, USA, 2005; p. 63.