Game On: Engaging Secondary Students in Evolution Learning

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Abstract

Enhancing science teaching requires strategies and resources that foster student motivation [1], often linked to the types of learning resources adopted [2]. Among these, educational games have demonstrated significant pedagogical benefits, serving as engaging tools that facilitate learning in an accessible and interactive manner [3,4]. The integration of game-based learning not only makes educational content more attractive but also creates a motivational environment conducive to knowledge acquisition [5]. This study aimed to investigate the effectiveness of educational games in promoting academic success through the implementation of the game "Lamarck Says". This game was designed to engage students in the principles of biological evolution according to Lamarckism, enabling them to simulate Lamarck's laws of evolution while fostering teamwork and competitive dynamics. The methodology was applied to an 11th-grade class (n=12), and its impact was assessed through a comparative analysis of students' performance before and after the intervention. The results were measured using V Gowin's epistemological tool, revealing an average post-intervention score of 87.2%, a significant improvement compared to the diagnostic test administered before the game's implementation (73.3%). The findings reinforce the potential of educational games as effective pedagogical tools for science teaching. By offering an engaging, interactive, and collaborative learning experience, the game significantly enhanced students' understanding of biological evolution. This aligns with previous studies highlighting the role of gamification in fostering student motivation and improving conceptual learning in science education [3,4,5]. Future research should explore the scalability of this approach in larger and more diverse students, as well as the long-term retention of knowledge gained through educational games.

Keywords: *Educational games; Biological evolution; Lamarckism; Science teaching.*

1. Introduction

As education professionals, it is essential to consider teaching, and particularly science education, as a means of including students in the environment that surrounds them and in what constitutes their interests and motivations. Thus, teaching can be regarded as a tool for social participation [6]. Miller and colleagues emphasize the importance of using evidence-based pedagogical practices that ensure equitable access to scientific knowledge, especially for students from diverse backgrounds [7]. It then becomes crucial to transition from a traditional approach to teaching, designed to be transversal and standardized, to one that reflects the individual characteristics of each class group or even each student in their personal identity. For this, it is necessary to break away from homogeneous practices and propose methodologies that consider all dimensions of students [8]. Furthermore, an analysis of international scientific production highlights the urgency of consolidating inclusive practices in science teaching, as pointed out by Johnson-Ojeda and his team in their study on the development and evaluation of teaching practices [9].

In recent years, the incorporation of game-based learning (GBL) into educational contexts has gained significant attention as an effective strategy to enhance student engagement and promote meaningful learning. This approach leverages the natural motivational appeal of games to facilitate knowledge acquisition, skill development, and active participation [1, 2]. Games, whether analogue or digital, provide dynamic and interactive environments where students can experiment, reflect, and apply concepts in a context that simulates real-life challenges, fostering deeper understanding and retention of scientific content [3].

The use of gamification and game-based applications in science education is particularly promising, as it allows the integration of playful elements such as challenges, competition, rewards, and immediate feedback, which are known to increase motivation and enhance learning outcomes [4, 5]. These active learning environments encourage collaboration and cooperative problem-solving, thereby promoting not only cognitive skills but also socio-emotional development. It has been shown that cooperative learning through gamified tasks significantly boosts creative problem-solving and student motivation compared to traditional approaches [14], reinforcing the potential of GBL as a powerful educational tool.

Moreover, GBL aligns with contemporary pedagogical paradigms that advocate for learner-centered teaching, where the teacher acts as a facilitator and mediator of knowledge rather than a mere transmitter [15]. This shift fosters autonomy and critical thinking, enabling students to become active agents in their learning journey. Meta-analyses on the effectiveness of digital educational games further corroborate these findings, highlighting medium to high when games are thoughtfully designed to incorporate educational objectives and engagement strategies [13]. The use of games thus supports not only content mastery but also transversal competencies essential for the 21st-century learner.

Given these benefits, the present study's choice to implement a GBL methodology reflects a deliberate strategy to enhance motivation and knowledge acquisition in a class of high-performance athletes, a group with specific time demands and motivational profiles. This approach is consistent with evidence-based recommendations to tailor teaching methods to student needs, promoting inclusion and equity in science education [6,7,10].

2. Methodology

Based on the methodological framework presented and within the scope of the Essential Learnings for the 11th-grade in secondary education – which advocate for exploring Lamarckism from a historical perspective on the evolution of life – a game entitled *Lamarck Manda* was implemented.

As for the research methodology, a mixed-methods approach was adopted, as both quantitative and qualitative data were collected. Educational research has shown significant growth in the use of mixed methods, enabling a broader and more comprehensive understanding of educational phenomena [16]. Quantitative data were collected through the initial administration of a diagnostic test and the subsequent production of a report based on Gowin's V report. The use of quantitative instruments, such as diagnostic tests, is essential for identifying students' prior knowledge and monitoring their progress over time [13].

Qualitative data was gathered using an observation grid applied throughout the lessons, which had already been implemented in the school under study. The integration of qualitative data, such as classroom observations, allows for a deeper analysis of pedagogical practices and educational interactions [14].

In any educational research, it is crucial to critically examine the study's context as well as the strategies and resources employed in the teaching and learning processes, aiming to ensure their greatest effectiveness [17]. This critical reflection is necessary to address the identified gaps, particularly to assess whether the use of an active methodology – specifically, GBL – promotes the development of students' knowledge and motivation regarding the topic of Lamarckism.

Knowledge development and motivation were thus considered the dependent variables under study, with the independent variable being the implementation of a cooperative game designed to foster teamwork and problem-solving skills. Consequently, a mixed-methods approach was adopted, with a strong instrumental focus on the collection of both quantitative and qualitative data [18]. Throughout the study, the following research techniques were employed: observation, record analysis, and testing. These techniques were supported by data collection instruments, including observation grids, a diagnostic test, and a Gowin's V report.

2.1. Sample

For the implementation of the explored game, 11th-grade students from a Portuguese public school were involved, with the particularity that they belonged to a class composed of high-performance athlete students from a basic and secondary school located in the central region of the city of Porto, Portugal. It is worth noting that, out of a total of twelve participants (n=12), seven were female (n=7; 58.3%) and five were male (n=5; 41.7%), with an average age of 16 years.

2.2. Data Collection Instruments

Considering the data collection methods used in the investigation, the following research instruments were employed: observation grid, diagnostic assessment test, and Gowin's V report. It is important to highlight that all the instruments used underwent processes that ensured their validity and reliability.

The observation grid aimed to assess the students' motivation across five performance levels, ranging from one to five. It was completed by three observers, and at the end, an arithmetic mean of the results from the three observations was calculated. It is worth noting that the grid was filled out during the execution of the activity.

The diagnostic test, administered before the exploration of the educational game, consisted exclusively of five multiple-choice questions and was applied through the digital platform Socrative, with a maximum score of 100 points. This instrument aimed to verify the students' prior knowledge about Lamarckism.

Finally, after the game's implementation, the students completed a Gowin's V report, scored on a scale up to 100 points, which included different types of responses: fill-in-the-blank, short answer, and extended answer.

2.3. Procedure

Regarding the implementation of the educational game, a key aspect was its facilitation outside the conventional four walls that define the classroom. Initially, the students received an activity card that, with the aim of sparking their curiosity, guided them to the sports field. It was then, in this unconventional environment for a Biology and Geology class, that the exploration of the game "Lamarck Says" began. Inspired by the traditional game "The King Says," in this didactic version, the character Lamarck takes the role of the king, and activity cards are handed out as the game progresses, with tasks for the players to complete, as shown in Table 1.

Table 1. Indication of each task to be performed on the activity cards.

Activity Card	Task
1	"Lamarck says... the class to go to the sports field."
2	"Lamarck says... read the QR code and answer the questions."
3	"Lamarck says... the class to divide into three teams. Teams should have members of similar height."
4	"Lamarck says... each team to collect the most balls of their color and place them in their basket. You have three minutes! Collecting more balls will bring an advantage for the future."
5	"Lamarck says... each member to tie the arm they used less in the previous step."
6	"Lamarck says... place the balls in the baskets. Note that higher baskets give more points."
Advantage	They can use a ladder to reach the baskets.

The objective of the game is for the students to understand the laws stated in Lamarckism in a more practical and visual way. When they must tie the arm they used less during the task, it aims to reflect the law of use and disuse. Meanwhile, the fact that those who collected more balls gain an advantage – the use of a ladder, which all team members used – refers to the law of the transmission of acquired characteristics.

The didactic game was implemented over the course of fifty minutes during a Biology and Geology class, with the first five minutes dedicated to the administration of a diagnostic test before starting the actual gameplay. At the end of the initially described period, an additional fifty minutes were used for completing Gowin's V and consolidating the knowledge acquired.

It is important to note that throughout the entire study, ethical considerations related to educational research were respected, with participation being voluntary, confidential, and anonymous.

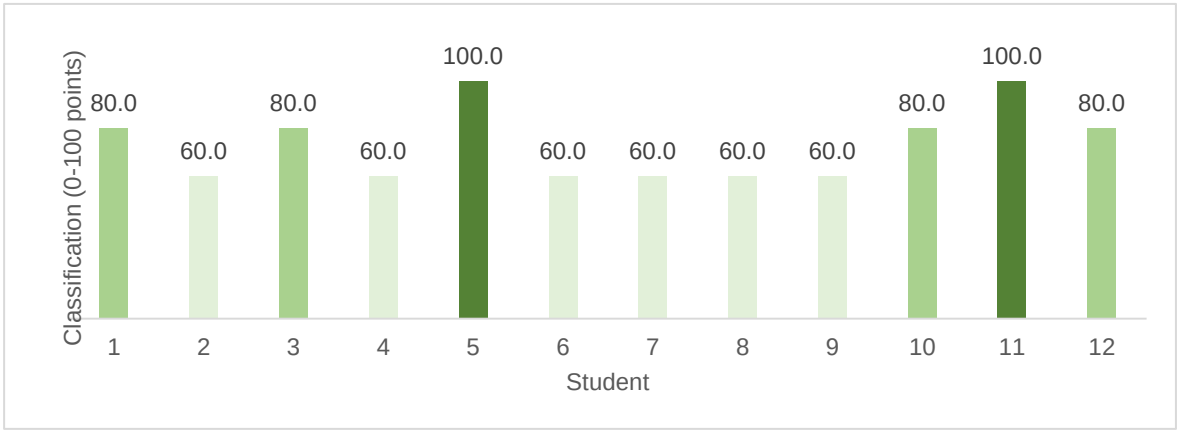
3. Results

Regarding the results obtained, to address the initially stated problem, the analysis focused on both the knowledge developed and the motivation of the students. Concerning knowledge, the average score on the diagnostic test was 73.3% (S.D.= 14.91). However, in the subsequent Gowin's V report, after the didactic game was explored, the average score increased to 87.3% (S.D.= 10.29), as shown in Table 2.

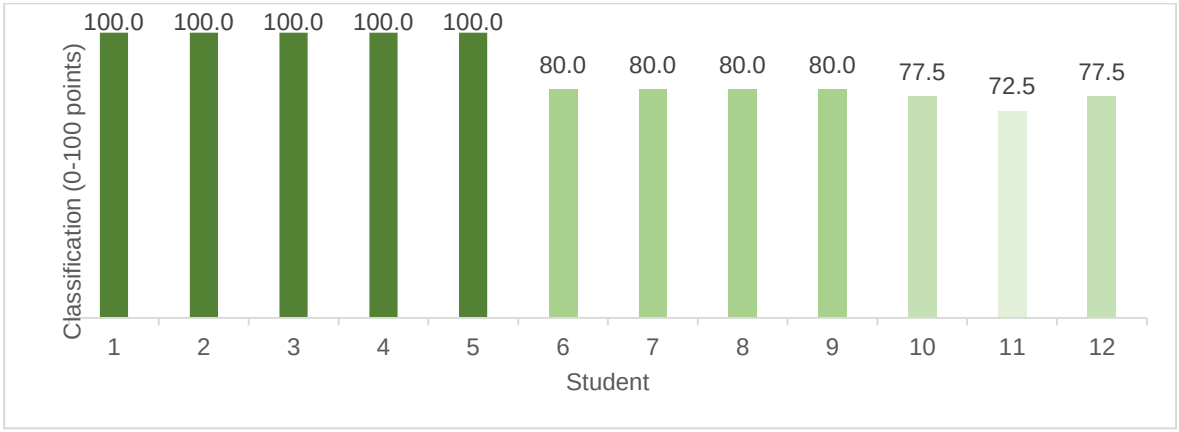
Table 3. Analysis of results obtained in the diagnostic test and in the Gowin's V report.

Instrument	Mean	Standard Deviation	Minimum	Maximum
Diagnostic Test	73.3	14.91	60.0	100.0
Gowin's V Report	87.3	10.29	72.5	100.0

Analyzing Graphs 1 and 2, which also represent the individual knowledge development of each student, it is possible to observe that, out of the twelve students in the study, eight (n=8; 66.7%) improved their performance comparing the results from both instruments, one (n=1; 8.3%) maintained the same score, and three (n=3; 25.0%) showed a decline in performance.

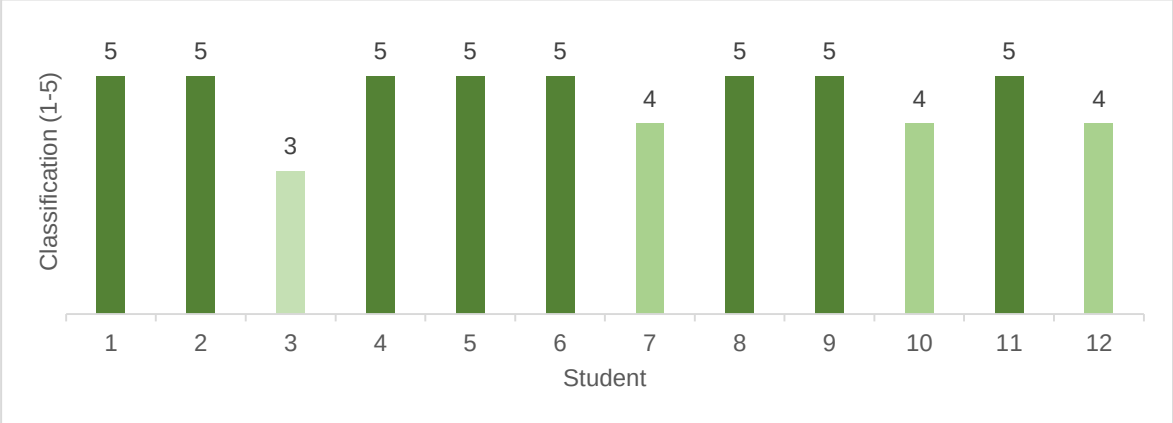


Graph 1. Individual student scores on the diagnostic test.



Graph 2. Individual student scores on the V of Gowin report.

Regarding student motivation, this was a key aspect in the creation and development of the activity, as the aim is for the school to be more than just a place where knowledge is acquired in an automated way. Thus, based on the records made by three observers, an average of the observations was calculated to obtain the results presented in Graph 3.



Graph 3. Motivation results obtained from the observation grid.

Based on the data collected through the observation grid, it is evident that the students were highly motivated, with eight out of the twelve participants showing the highest level of motivation (level five), three at level four, and only one at level three. In this way, it is possible to observe—and in comparison with the results regarding knowledge acquisition—that all students who demonstrated high levels of motivation improved their performance in terms of knowledge.

After analyzing the motivation results, and as expected given the individual characteristics of the class, most students recorded the highest motivation level during the implementation of a lesson using educational games.

4. Discussion

The results of this study highlight the potential of GBL methodologies as effective strategies for increasing student motivation and enhancing knowledge development – particularly among high-performance athletes who face unique challenges in balancing academic and athletic demands. These findings align with prior research indicating that active methodologies can foster engagement and deeper learning across diverse student populations [12,13].

The notable improvement in student performance – reflected in the rise from an average score of 73.3% on the diagnostic test to 87.3% on the Gowin's V report – demonstrates the pedagogical efficacy of educational games. This supports Cheng et al.'s meta-analytic findings that digital and analogue GBL significantly benefits students' performance, especially when the design aligns with clear educational objectives [13]. In this case, the practical tasks embedded in the "*Lamarck Manda*" game effectively illustrated Lamarck's evolutionary laws, contributing to both conceptual understanding and retention.

Motivation also emerged as a crucial factor in learning outcomes. Students who demonstrated the highest levels of motivation (levels four and five) were those who most improved in knowledge assessments. This corroborates Wong et al.'s conclusions that gamified cooperative learning environments enhance creative problem-solving and intrinsic motivation more effectively than traditional cooperative approaches [14]. The playful, competitive nature of the activity – set in a sports-related context – resonated with the students' identities as athletes and created a meaningful learning experience. According to Carreiras, adapting teaching strategies to student characteristics not only fosters inclusion but also leads to more effective and enga ging learning [10].

This contextualized and personalized approach also supports broader calls for inclusive and equitable teaching practices. Johnson-Ojeda et al. emphasize the need for instructors to develop pedagogical strategies that reflect and respond to the identities and experiences of their students [9]. In this regard, the current study exemplifies how inclusive education can be enacted through innovative didactic designs that transcend traditional classroom settings.

Moreover, the mixed-methods approach adopted in this research enriched the analysis by combining performance data with observational insights. As Onwuegbuzie et al. note, mixed methodologies provide a more holistic understanding of complex educational dynamics [16], and this was evident in how both quantitative and qualitative data aligned to reinforce the study's findings.

These results also hold implications for future educational practices. They suggest that GBL can be especially impactful in contexts requiring flexible, high-engagement methods, such as among students with dual careers (academic and athletic). Incorporating elements that reflect students' lived realities – such as competition, movement, and teamwork – can enhance both motivation and learning outcomes.

For future research, it would be valuable to explore the longitudinal impact of repeated game-based interventions, the role of individual motivational profiles, and the adaptability of such methodologies across different content areas and student populations. Furthermore, integrating digital versions of these games could leverage technology's affordances and further enhance scalability and accessibility [5].

5. Conclusion

The results obtained in this study clearly highlight the potential of active methodologies, particularly GBL, as effective pedagogical tools for promoting motivation and learning, especially in educational contexts involving students with specific profiles, such as high-performance athletes. The activity *"Lamarck Manda"*, developed based on principles of cooperative, active, and inclusive learning, not only led to a significant increase in students' motivation levels but also resulted in substantial academic improvement, as evidenced by the comparison between the initial diagnostic test and the Gowin's V report.

By integrating the students' athletic and competitive context into the classroom dynamic, the didactic approach proved especially effective, allowing for a connection between scientific content and students' lived experiences. This alignment between formal knowledge and personal reality contributed to a deeper understanding of the concepts addressed while also valuing the students' identities and fostering a more inclusive, equitable, and meaningful learning environment.

Moreover, the study emphasizes the importance of pedagogical practices that break away from traditional, homogeneous methodologies and adapt to the specific needs of each class group. The use of games as an educational resource proved promising not only for capturing students' interest but also for fostering key skills such as teamwork, critical thinking, problem-solving, and self-regulated learning.

Nevertheless, some limitations of the study must be acknowledged, particularly the small sample size and the specificity of the group involved. These factors limit the generalizability of the findings, and thus, future research is recommended with larger and more diverse samples, as well as the application of this methodology in different educational contexts and subject areas. Longitudinal studies analyzing the medium- and long-term impact of such practices could also contribute to a deeper understanding of the effectiveness of GBL in consolidating knowledge.

In conclusion, this research reinforces the urgent need for pedagogical innovation in science education and highlights the importance of considering students' individual characteristics when designing educational strategies. Promoting a more active, inclusive, and reality-connected education is not only desirable – it is essential for ensuring academic success in a system that aspires to be equitable, motivating, and transformative.

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