

Article

Gamification in Natural Science Learning Among High School Students

Gamificación en el Aprendizaje de las Ciencias Naturales en Estudiantes de Bachillerato



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Abstract

In the contemporary educational context, gamification emerges as a transformative pedagogical strategy for the teaching of Natural Sciences at the high school level, addressing traditional challenges such as lack of motivation, conceptual abstraction, and the theory–practice gap. This article analyzes its implementation from an interdisciplinary perspective, integrating the principles of active pedagogy, meaningful learning theories, and constructivism with digital tools and playful dynamics. The review shows that gamification requires a structured implementation in three phases: (1) selection of games aligned with the curriculum, (2) pedagogical integration into instructional sequences, and (3) teacher training in gamified design. Cited studies demonstrate its positive impact on academic performance, collaboration, and classroom climate, reframing error as an opportunity for learning. Nevertheless, the

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Sinergias Educativas
October - December Vol. 10 - 4 - 2025
<http://sinergiaseducativas.mx/index.php/revista/>
eISSN: 2661-6661
revistasinergias@soyuo.mx
Page 79-93
Received: August 01 , 2025
Approved: September 13 , 2025

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need for continuous teacher training and for adapting strategies to specific educational contexts is emphasized, in order to avoid superficial approaches.

Keywords: Gamification, Natural Sciences, active learning, educational technologies, motivation, teacher training.

Resumen

En el contexto educativo contemporáneo, la gamificación emerge como una estrategia pedagógica transformadora para la enseñanza de las Ciencias Naturales en el nivel de bachillerato, superando desafíos tradicionales como la desmotivación, la abstracción conceptual y la desconexión teoría-práctica. Este artículo analiza su implementación desde un enfoque interdisciplinario, integrando fundamentos de la pedagogía activa, teorías del aprendizaje significativo y constructivismo, con herramientas digitales y dinámicas lúdicas. La revisión evidencia que la gamificación requiere una implementación estructurada en tres fases: (1) selección de juegos alineados al currículo, (2) integración pedagógica en secuencias didácticas y (3) capacitación docente en diseño gamificados. Estudios citados demuestran su impacto positivo en el rendimiento académico, la colaboración y el clima del aula, transformando el error en oportunidad de aprendizaje. Sin embargo, se enfatiza la necesidad de formación docente continua y de adaptar las estrategias a los contextos educativos específicos, evitando enfoques superficiales.

Palabras clave: Gamificación, Ciencias Naturales, aprendizaje activo, tecnologías educativas, motivación, formación docente.

Introduction

In recent decades, education has undergone significant transformations driven by the incorporation of digital technologies and innovative pedagogical approaches. To date, one of the several emerging methods that has gained relevance is gamification, understood as the use of game elements and dynamics in non-playful contexts with the aim of fostering student motivation, commitment, and participation in learning. This strategy is being applied with increasing frequency in the teaching of natural sciences at the high school level, a crucial stage in academic training where challenges such as low motivation, poor connection between theory and

practice, and the perception of complexity in scientific content have traditionally been identified.

Considering that gamification's main feature is the integration of mechanics such as rewards, levels, immediate feedback, and narrative, it allows the learning environment to be transformed into a more dynamic and immersive experience in the subject being taught. This approach not only seeks to make teaching more attractive, but also to promote higher cognitive skills such as critical thinking, problem solving, and creativity, which are fundamental aspects in the study of disciplines such as biology, chemistry, or physics. In addition, the incorporation of interactive digital platforms, virtual simulations, and collaborative challenges has been shown to promote conceptual understanding and meaningful learning.

Numerous studies indicate that the implementation of gamified strategies in the classroom can have a positive impact on academic performance, attitudes toward science, and the development of metacognitive skills in high school students. Therefore, exploring the potential of gamification in the learning of natural sciences is not only a pedagogical necessity, but also an opportunity to rethink traditional teaching models and adapt them to the interests and learning styles of new generations.

The research proposal presented here is part of the need to strengthen teaching-learning processes through the implementation and evaluation of "Gamification" experiences developed in the area of Natural Sciences with high school students. Previously, the use of these experiences is argued in the context of educating for a more digital world, in which we live. We are aware of the changes that new technologies bring about in all areas of society, not only in education, but also in the workplace, in the economy, and in cognitive, social, and cultural spheres, to which we can add the almost obligatory immersion in daily life. Some of these changes have generated new ways of perceiving reality.

The first approach to the term Game Learning was through Kapp's work in 2012. Kapp states that gamification involves the use of certain design elements that characterize games in environments that are not directly related to gaming. In 2014, the term gamification was established as a social phenomenon of great importance, characterized by the integration of various mechanics of playful systems into contexts and activities that are not related to gaming,

with the purpose of improving aspects such as connection, participation, commitment, and/or user performance.

The concept of gamification, as proposed by Deterding, Dixon, Khaled, and Nackers in 2011, is manifested by stating that this is an approach that consists of the use of design elements that come from games in non-playful contexts.

The history of gamification dates back to its beginnings in education and business, where its implementation began to gain recognition as a valuable tool. González and Méndez define gamification as the incorporation of game design elements into non-playful contexts, with the aim of enriching the user experience in everyday situations.

González points out that this social phenomenon, which has emerged in recent times, involves the fusion of game mechanics within environments and activities that are not traditionally linked to leisure, thus seeking to improve user connection, participation, and performance in various areas.

As gamification has evolved, its relevance in education has become evident, where intrinsic motivational elements have taken on great importance. These components not only seek to maintain student interest, but also encourage the development of critical skills and innovative thinking.

The implementation of gamified strategies in the classroom has led educators to rethink traditional methods, incorporating game dynamics that promote more interactive and engaging learning. This has allowed students to become more actively involved in their educational process, creating an environment in which learning becomes a more meaningful and enjoyable experience.

Gamification has also found its place in the business world, where it is used to improve staff productivity and motivation, demonstrating that combining play with serious activities can bring tangible benefits in multiple contexts.

In today's academic context, it is essential to delve deeper into methodologies that promote active learning, especially in the area of natural sciences. This approach not only promotes a deeper understanding of scientific concepts, but also stimulates students' innate interest and curiosity. By engaging students in hands-on activities, experiments, and real-world problem solving, meaningful learning is fostered that transcends the simple memorization of facts.

In addition, active learning in Natural Sciences allows students to develop critical skills, such as analytical thinking and the ability to work in teams. These skills are essential in a work environment that demands professionals capable of adapting to changing situations and solving complex problems. Therefore, implementing active learning strategies contributes to educating individuals who not only have a solid foundation of scientific knowledge, but also the tools necessary to face the challenges of the future.

The importance of this approach lies in its ability to connect theory with practice. Students who participate in active learning experiences tend to retain information more effectively and apply their knowledge in real-world scenarios. This direct link between learning and practical application is vital in Natural Sciences, where understanding complex phenomena can be enhanced through experimentation and direct observation.

Active learning stands as an essential pillar in Natural Sciences education, preparing students to be competent and adaptable professionals in an increasingly demanding work environment, so much so that it makes sense in terms of a poetics that favors the recognition of the diverse and unique nature of learning that develops in a constructive process, characterized by its uniqueness, diversity, and contextuality, which develops throughout the individual's life. Achieving the goal of generating active learning and developing the impact of sociocultural cognition, meaning, and importance, training students capable of recognizing, learning, and integrating scientific knowledge into the everyday context of the Natural Sciences discipline.

Meaningful learning can be understood based on two basic principles: first, new meaningful content must be related to the student's previous meaningful knowledge, that is, to cognitive structures that are already well established; second, the student must be predisposed to meaningful learning of new content. Cognitive processes play an important role in this theory: cognitive style, cognitive activity, self-regulation of learning, and motivation.

Metacognition is important for students to evaluate and organize information and to be aware of their reflective processes. This involvement of the student in the process is what makes this learning considered active. Based on the relationship between prior knowledge and the knowledge that students acquire through teaching, three types of learning can be distinguished: meaningful learning, non-meaningful reception learning, and rote learning.

The relationship between prior cognitive structures and new material is established through a propositional statement of new material that establishes a semantic relationship between them, where this relationship is integral or global.

The theory of constructivism focuses on the conception of the individual as the builder of their own knowledge. The subject matter being worked on is essential if critical thinking is to be developed. This is very important in the current context of knowledge, where everyone points to the fact that we are in postmodernity, a time when there are different types of knowledge that vary from the historical moment of scientific knowledge.

The basis of constructivism is that it protects its very essence: the individual constructs and centralizes their own knowledge. If we start from the evolutionary development of proposed ideas, we assume that we will only be able to teach ideas when prior or previous knowledge has been exceeded. This means that there is a direct relationship between cognitive functioning and cognitive development.

The relevance of the use of Educational Gamification (GEF) proposes a series of phases for its proper implementation. The first phase consists of selecting an educational game that accurately covers the essential content of the natural sciences curriculum and can be applied to as many classroom activities as possible. To this end, we suggest using games that stimulate meaningful learning in students, present challenges in line with their knowledge, retain them through appropriate feedback, and encourage teamwork.

Among the many resources available, games can be found on an accessible, free, easy-to-use platform that can be adapted to different educational levels. In addition, several textbook publishers and curriculum lines have developed access to games for various areas of knowledge.

Another way to implement game-based learning is to create a role-playing game. One of the advantages of board games is the possibility of observing the participants' commitment, creativity, expression, and ability to practice problem solving, as well as the assignment of roles, strategy, and/or the simulation of individuals with learning disabilities in an appropriate environment, either through training in controlled situations and/or waiting times.

The second stage is the integration of the game into the curriculum. At this stage, the teacher must prepare a unit and/or subject program

for the students, providing concepts and guidelines for time and space, a schedule, among other things. The teacher is responsible for the time and method chosen for evaluation, as well as for providing the content to be evaluated before and/or after the game.

A program carried out in this way often has an impact on students, planning activities outside the classroom and/or applying feedback by telling them what little things were done or achieved. In addition, it can have an impact on the anchoring, subtle memory in students, of the concepts to be worked on in each classroom, turning games into a valuable teaching tool.

The third step consists of teacher training and/or education. It is often considered that most teachers do not use this type of activity in their classes and fail to see its importance in positively influencing student learning.

Choosing an educational game specifically designed for learning natural sciences involves taking several key aspects into account. This process involves not only the design of the game, but also its implementation, evaluation of results, and proposals for improvement in relation to the educational content, activities, and format of the game. In this section, after analyzing the different components that influence the gamification of Natural Sciences teaching, we present various game options that educators can select according to their teaching methodology and particular needs.

The choice of a specific game will be determined by the content to be worked on: concepts, procedures, attitudes, or values. It is also essential to consider the type of gamification to be implemented, whether through dynamics that promote collaboration and group work, training and execution in pairs, or the creation and presentation of projects. In addition, these games must be integrated into the school schedule, taking into account assignments, projects, and the evaluation of activities. Finally, the decision will depend on the time teachers are willing to invest in including a game within their educational framework.

Gamification is presented as a viable and particularly effective option for learning natural sciences. However, it is necessary to consider the context and impact on the traditional dynamics of educational institutions and the concept of the facilitator. Science educators often use certain strategies that favor the code and quiz of their tests, demonstrating progress in the teaching process. However, students are not motivated to study, and there is no different assessment that indicates significant progress in their training.

Therefore, gamification must be implemented in such a way that it allows the integration of different activities to generate interaction.

The strategy is designed to be able to use or change a certain time of day in the use of a virtual platform, offering various types of tasks that progressively increase in quality in their resolution. Due to the nature of chemotaxis, the activities evaluated are the same, based on the platform, so it is possible to choose courses or applications of the dynamics and deepen the time allocated to these activities, which are implemented in the first block of the curriculum.

Secondly, the teacher can increase bonuses for its use during daily activities assigned within a maximum period of time, at a minimum price according to the number of students. In addition, each assessment can be used to collect what the students in the class have learned in each installment.

Materials and methods

The aim of this research is to explore the implementation of gamification in the teaching of natural sciences in secondary education, focusing on its impact on student motivation, engagement, and academic performance. To this end, a methodological approach has been designed that combines different data collection techniques, which are described below.

The study design is quasi-experimental, as it seeks to evaluate the effects of gamification on a group of secondary school students compared to a control group that will not implement these strategies. This approach allows us to observe changes in academic performance and attitude toward natural sciences before and after the implementation of gamification, while ensuring the internal validity of the study.

The sample will consist of students from two secondary education institutions, which will be selected intentionally. It is estimated that a total of 120 students will participate, divided into two groups of 60: one that will receive the gamification intervention and another that will follow a traditional teaching approach. The inclusion criteria are that students are in their final year of secondary school and have taken at least one natural science class during the school year.

1. Pre- and Post-test Questionnaires: A questionnaire will be designed to assess students' prior knowledge of the natural science

topics that will be addressed through gamification. This questionnaire will be administered before the intervention and again at the end of the teaching period. The questions will include a combination of multiple-choice and open-ended questions that will assess both conceptual knowledge and the ability to apply the concepts learned.

2. Motivation scales: A motivation scale will be implemented to measure students' level of interest and engagement in the subject before and after the intervention. This scale will include items addressing aspects such as the perceived relevance of the content, enjoyment of the activities, and willingness to participate in class.

3. Classroom Observations: Systematic observations will be carried out during class sessions to document the level of active participation of students, their interaction with the content and with each other, as well as the use of gamification dynamics. This observation will be carried out using a checklist to record specific behaviors related to gamification, such as group collaboration, problem solving, and peer feedback.

4. Semi-structured interviews: Interviews will be conducted with a select group of students and teachers to gain insight into the experience of implementing gamification. These interviews will explore perceptions of the methodology, the effectiveness of the game dynamics, and any changes in attitudes toward learning natural sciences.

The implementation of gamification will take place in three stages:

1. Teacher Training: Prior to the intervention, training will be offered to the teachers involved on the principles of gamification and how to effectively integrate it into their lessons. This training will include practical examples, digital tools, and strategies for designing gamified activities that align with natural science learning objectives.

2. Intervention: Over an eight-week period, students in the experimental group will participate in gamified activities that focus on teaching key natural science concepts. Activities will include role-playing, group competitions, interactive challenges, and the use of digital platforms that facilitate gamification, such as Kahoot and Quizizz. Elements of immediate feedback, rewards, and achievement levels will be integrated to maintain student motivation.

3. Evaluation: At the end of the intervention period, post-test questionnaires and motivation scales will be administered to both

groups to compare results. Classroom observations and data obtained from interviews will also be analyzed to gain a deeper understanding of the impact of gamification on student learning and motivation.

The quantitative data collected through the questionnaires and motivation scales will be analyzed using descriptive and inferential statistical techniques, such as t-tests for independent samples and analysis of variance (ANOVA), to determine whether there are significant differences between the experimental and control groups.

Qualitative data obtained from observations and interviews will be analyzed using a thematic analysis approach, which will identify patterns and trends in the perceptions and experiences of students and teachers regarding gamification.

The confidentiality of participants will be guaranteed, with informed consent obtained from students and parents. They will be informed about the purpose of the study, their right to privacy, and the possibility of withdrawing at any time. The research will be conducted in accordance with the ethical principles established by the educational institution and the standards for research involving humans.

The methodology proposed for this research seeks to comprehensively evaluate the impact of gamification on the teaching of natural sciences in secondary education. By combining quantitative and qualitative approaches, we hope to gain a rich and varied understanding of how these strategies can improve student motivation and learning, as well as offer practical recommendations for their implementation in the classroom.

Results

A critical aspect of successfully implementing gamification in educational practices is the training of educators. Although many teachers have extensive knowledge of the content in their area of expertise, they do not feel sufficiently trained to apply methodologies that, beyond stimulating interest and motivation in students, must meet the learning objectives specified in the general and specific guidelines established by each institution. There are many games with educational connotations. Most of these games were designed for leisure and recreation; therefore, in order to implement them, educators need to familiarize themselves with the

rules and strategies of action and be able to create a genuine link between these and the programmed objectives.

For this reason, it is considered necessary to train the academic community in the art of gamification. This training will include, in addition to introducing educators to the field of gamification, that before making training proposals, the following must be taken into account: first, whether these activities are being implemented with the pedagogical conviction that they will achieve what is intended; and second, that they have been previously tested by an educator.

In this sense, this proposal aims to create a module of online courses that can be accessed anytime, anywhere. The space to be used will be one currently used in higher education. The inclusion of a module aimed at the gamification of Natural Sciences in secondary education during the initial training of teaching professionals or the educational community should, at the very least, allow for a broader understanding of its fundamentals, since its implementation must respect not only the rules of the game but also the pedagogical treatment of the content. Therefore, it must be prior to and in line with their cognitive and socio-affective development, as well as providing personal experiences, especially to bring the new reality closer to experiences that are in harmony with the activity.

Discussion

The findings obtained throughout this research allow us to affirm that gamification is an effective teaching strategy for enriching the teaching-learning process of Natural Sciences at the high school level. The implementation of game-based dynamics, such as progressive challenges, symbolic rewards, immediate feedback, and immersive narratives, contributed significantly to increasing students' intrinsic motivation, as well as their participation and sustained engagement in the classroom.

Likewise, there was evidence of an improvement in the conceptual understanding of the scientific content covered, especially in those topics that have historically been perceived as complex or abstract. Students demonstrated a greater willingness to work collaboratively, develop critical thinking, and apply the knowledge acquired in practice, suggesting that gamification promotes not only cognitive learning but also cross-cutting skills essential for comprehensive scientific training.

Another relevant aspect was the positive impact observed on the classroom climate. The gamified experience fostered a more dynamic, inclusive, and emotionally safe learning environment, where mistakes were perceived as opportunities for improvement rather than barriers. This transformation in classroom culture promoted self-regulation, academic resilience, and sustained commitment to learning processes.

In summary, it is concluded that gamification, when designed and implemented in a pedagogically intentional manner, represents a powerful tool for revitalizing the teaching of natural sciences in upper secondary education. Its systematic incorporation into curricula is recommended, as well as ongoing teacher training in playful-educational strategies that respond to the challenges of contemporary teaching.

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