GAMIFICATION AS AN INTERDISCIPLINARY PEDAGOGICAL DEVICE IN NATURAL SCIENCES EDUCATION: ANALYSIS OF ITS IMPACTS ON MEANINGFUL LEARNING IN LIGHT OF AUSUBEL'S THEORY

https://doi.org/10.63330/aurumpub.046-007

Marcelo Damião Amoras Nascimento[1], Ana Clara de Sousa Meirelles[2], Kelcione Pinheiro Lima Joter[3], Anderson Fernandes de Carvalho Farias[4], Rafael dos Santos Nardotto[5], Matheus Vinicius da Silva Barros[6], Boaventura da Silva Leite Filho[7] and Neudson Rosa Gonçalves[8]

[1] Master's Student in Emerging Technologies in Education
Metropolitan University of Science and Technology - MUST, Florida USA
E-mail: mdanascimento@hotmail.com
Lattes: https://lattes.cnpq.br/7724892056191052
ORCID: https://orcid.org/0009-0009-4785-5253
[2] Doctoral Student in Biotechnology
Universidade Federal do Delta do Parnaíba - UFDPAR, Parnaíba PI
E-mail: anameirelles83@gmail.com
Lattes: https://lattes.cnpq.br/8252342729270577
ORCID: https://orcid.org/0000-0002-3085-2138
[3] Master's Degree in Health Management
Universidade Estadual do Ceará - UECE, Fortaleza CE
E-mail: kelcione@gmail.com
Lattes: https://lattes.cnpq.br/5346765451538154
ORCID: https://orcid.org/0009-0006-8120-4858
[4] International Master's Degree in Medicine
Esneca Business School - ESNECA, Zaragora AR
E-mail: andersonfercalho@gmail.com
Lattes: https://lattes.cnpq.br/3357217652638543
ORCID: https://orcid.org/0000-0002-4326-9689
[5] Master's Degree in Teaching – Chemistry
Universidade Estadual do Norte do Paraná - UENP, Cornélio Procópio PR
E-mail: rafaelsantosquimica2012@gmail.com
Lattes: https://lattes.cnpq.br/2720118155933737
ORCID: https://orcid.org/0000-0002-7106-3231
[6] Postgraduate Degree in Criminal Law and Criminal Procedure
Universidade Presbiteriana Mackenzie - MACKENZIE, São Paulo SP
E-mail: mattbarros@hotmail.com
Lattes: https://lattes.cnpq.br/7512914831636248
[7] Master's Student in Education Sciences
Universidad Del Sol - UNADES, Asunción PY
E-mail: boaventureprof@yahoo.com.hr
Lattes: https://lattes.cnpq.br/6265097111700070
ORCID: https://orcid.org/0009-0008-5173-4238
[8] Master's Student in Education Sciences
Universidad Del Sol - UNADES, Asunción PY
E-mail: neudsonrosa@gmail.com
Lattes: https://lattes.cnpq.br/8905758540312108
ORCID: https://orcid.org/0009-0008-0169-5541

Abstract

Gamification has emerged as an active methodology capable of enhancing the teaching-learning process, particularly in Natural Sciences education. This study aimed to analyze the impacts of gamification as an interdisciplinary pedagogical device in promoting meaningful learning, based on David Ausubel's theory. It is a qualitative literature review conducted in the ERIC, SciELO, Latindex databases, and institutional repositories, considering publications from 2022 to 2026. The results indicated that gamification promotes student engagement, motivation, and active participation, in addition to fostering cognitive skills such as critical thinking and problem-solving. Furthermore, the use of game elements, such as challenges, rewards, and narratives, facilitates the anchoring of new knowledge to prior knowledge, enabling meaningful learning. The interdisciplinary approach proved essential for integrating Natural Sciences content, contributing to a more contextualized understanding of scientific phenomena. However, challenges were identified, including the need for adequate teacher training, pedagogical planning, and access to technological resources. It is concluded that gamification, when applied intentionally and grounded in theory, represents a promising strategy for innovation in science education, contributing to the development of more meaningful and lasting learning.

Keywords: Active methodologies, Gamification, Interdisciplinary teaching, Meaningful learning, Natural sciences.

INTRODUCTION

Contemporary education has been marked by significant transformations that demand the adoption of innovative methodologies capable of promoting greater engagement and effectiveness in the teaching-learning process. In this context, gamification emerges as a relevant pedagogical device, characterized by the application of elements typical of games in educational environments, with the aim of stimulating students' active participation and fostering the construction of knowledge (Curvo; Mello; Leão, 2023). In Natural Sciences education, this approach assumes a strategic role by enabling the integration of content

from different areas, promoting more dynamic, contextualized, and interdisciplinary learning (Queiroga; Pacheco, 2024).

The use of gamification in the school environment has demonstrated potential to overcome traditional pedagogical practices centered on the transmission of content and on mechanical memorization. By incorporating elements such as challenges, rewards, immediate feedback, and engaging narratives, this methodology contributes to increasing students' motivation and engagement, in addition to fostering the development of cognitive, social, and emotional skills (Neto; Penteado; Carvalho, 2023; Feliciano et al., 2023). Studies show that its application in subjects such as Biology, Chemistry, and Physics has led to improvements in academic performance and greater interest in scientific content (Silva; Zanelato, 2024; Pereira; Leite, 2025; Teixeira; Valle, 2025).

Furthermore, international research indicates that gamification can promote the development of critical thinking, autonomy, and self-regulation of learning, especially when associated with digital technologies and interactive environments (Alahmari et al., 2023; Zourmpakis; Kalogiannakis; Papadakis, 2023; Ateş; Polat, 2025). In this sense, the integration of resources such as augmented reality and gamified digital platforms expands teaching possibilities, making learning more meaningful and aligned with the demands of contemporary society (Ahmed et al., 2025; Zarror; Sumaryati; Sukmawati, 2025).

However, despite the advances evidenced in the literature, there are still gaps regarding the understanding of the impacts of gamification on the promotion of meaningful learning, especially when analyzed from an interdisciplinary perspective in Natural Sciences education. Thus, the following research problem is defined: how does gamification, as an interdisciplinary pedagogical device, contribute to the promotion of meaningful learning in Natural Sciences education in light of Ausubel's theory?

Given this problem, the general objective of this study is to analyze the impacts of gamification on the promotion of meaningful learning in Natural Sciences education, grounded in the theoretical assumptions of David Ausubel. The specific objectives are: (i) to discuss the foundations of gamification

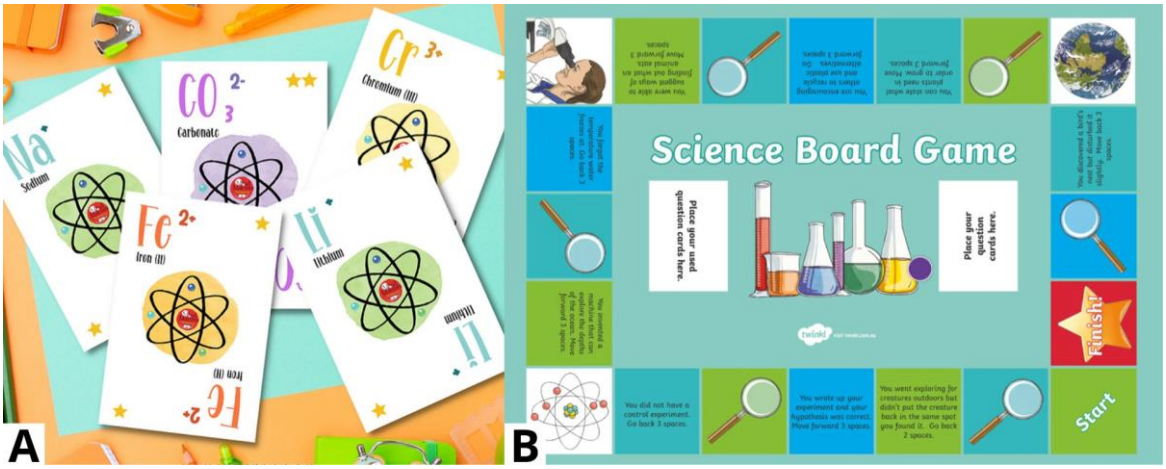
as an active methodology in science education; (ii) to understand the principles of the theory of meaningful learning; (iii) to analyze empirical evidence on the use of gamification in different areas of the Natural Sciences; and (iv) to identify the contributions and limitations of this approach in the teaching-learning process.

The justification for this study is based on the need to investigate pedagogical practices that promote more meaningful learning, considering the challenges faced in the educational context, such as student demotivation and the fragmentation of knowledge. The theory of meaningful learning proposed by Ausubel emphasizes that learning occurs more effectively when new information is related to relevant prior knowledge, allowing structured and lasting assimilation (Farias, 2022; Costa Júnior et al., 2023). In this sense, gamification can act as a mediating strategy that facilitates this connection, making content more accessible and contextualized (Siqueira et al., 2026).

In the following paragraph, Figure 1 is presented, illustrating examples of gamification strategies applied to Natural Sciences education, highlighting elements such as scoring systems, levels, challenges, missions, scientific narratives, and the use of interactive digital technologies, which contribute to making the learning process more engaging and meaningful.

Figure 1

Examples of gamification strategies in Natural Sciences education



Source: A) Play Card Games to teach Ionic Bonding and Chemical Formulae (2024); B) Science Board Game (2024)

With regard to the theoretical framework, meaningful learning, according to Ausubel, is based on the interaction between new knowledge and pre-existing cognitive structures, called subsumers, allowing learning to occur in a non-arbitrary and non-literal manner (Sexton, 2025). This perspective stands in contrast to mechanical learning, characterized by memorization without understanding, which is still predominant in many educational contexts (Rocha et al., 2026). Studies indicate that active methodologies, such as the use of concept maps and interactive strategies, favor this type of learning by promoting the organization and integration of knowledge (Mossi; Vinholi Junior, 2022; Gaudêncio et al., 2023).

At the same time, gamification has been widely discussed as an active methodology capable of enhancing meaningful learning. Research demonstrates that the use of playful elements in science education contributes to the active construction of knowledge, stimulating curiosity, inquiry, and problem-solving (Camatta, 2025; Santos et al., 2025). Moreover, the interdisciplinary approach, by integrating different areas of knowledge, makes possible a broader understanding of scientific phenomena, favoring the contextualization of content and meaningful learning (Arcanjo Filho; Martins, 2025).

In this context, the articulation between gamification, interdisciplinarity, and meaningful learning represents a promising field for pedagogical innovation in Natural Sciences education. Recent studies highlight that gamification, when applied in a planned manner and aligned with clear educational objectives, can contribute significantly to the development of students' cognitive and socioemotional competencies (Papadakis; Zourmpakis; Kalogiannakis, 2022; Santos Rey; Linhares; Borba-Pinheiro, 2025). Thus, it becomes essential to deepen investigations into this theme in order to support teaching practices that are more effective, inclusive, and contextualized.

Thus, this research is situated within the field of discussions on pedagogical innovation, seeking to understand how gamification, articulated with Ausubel's theory of meaningful learning, can contribute to the construction of a more integrated, dynamic, and meaningful Natural Sciences education.

METHODOLOGY

This research is characterized as a literature review with a qualitative approach, descriptive and exploratory in nature, aimed at analyzing the contributions of gamification as an interdisciplinary pedagogical device in Natural Sciences education, with a focus on promoting meaningful learning in light of Ausubel's theory. The choice of this methodological design is justified by the possibility of gathering, analyzing, and synthesizing recent scientific productions, allowing an in-depth understanding of the state of the art regarding the theme under investigation.

The study was guided by the following research question: how does gamification, as an interdisciplinary pedagogical device, contribute to the promotion of meaningful learning in Natural Sciences education in light of Ausubel's theory? This question guided all stages of the research, from the definition of search strategies to the analysis of the selected studies.

For data collection, a systematized search was carried out in databases recognized in the educational and scientific field, namely: Education Resources Information Center (ERIC), Scientific Electronic Library Online (SciELO), Latindex, and institutional repositories of national and international universities. These sources were selected due to their academic relevance and broad coverage in indexing studies focused on education, science teaching, and active methodologies.

The time frame adopted comprised publications between the years 2022 and 2026, with the aim of including recent and up-to-date productions on the topic. The search strategy used descriptors in Portuguese and English, combined through Boolean operators (AND and OR), such as: "gamificação," "ensino de ciências," "aprendizagem significativa," "David Ausubel," "metodologias ativas," "gamification," "science education," and "meaningful learning." These terms were selected based on their relevance to the theme and their frequency of use in scientific studies in the field.

As inclusion criteria, the following were considered: (i) full scientific articles available in their entirety; (ii) studies published between 2022 and 2026; (iii) publications in Portuguese, English, and Spanish; (iv) research addressing gamification in the context of Natural Sciences education or related

areas (Biology, Physics, and Chemistry); and (v) studies presenting a relationship with meaningful learning or with Ausubel's theory. On the other hand, the exclusion criteria involved: (i) duplicate works; (ii) studies not directly related to the proposed theme; (iii) abstracts, reviews, editorials, and opinion articles; and (iv) publications with restricted access or unavailable in full.

The study selection process took place in stages. Initially, the titles and abstracts were read in order to identify relevance to the theme. Next, the previously selected articles were read in full, allowing a more careful analysis of their relevance and contribution to the study.

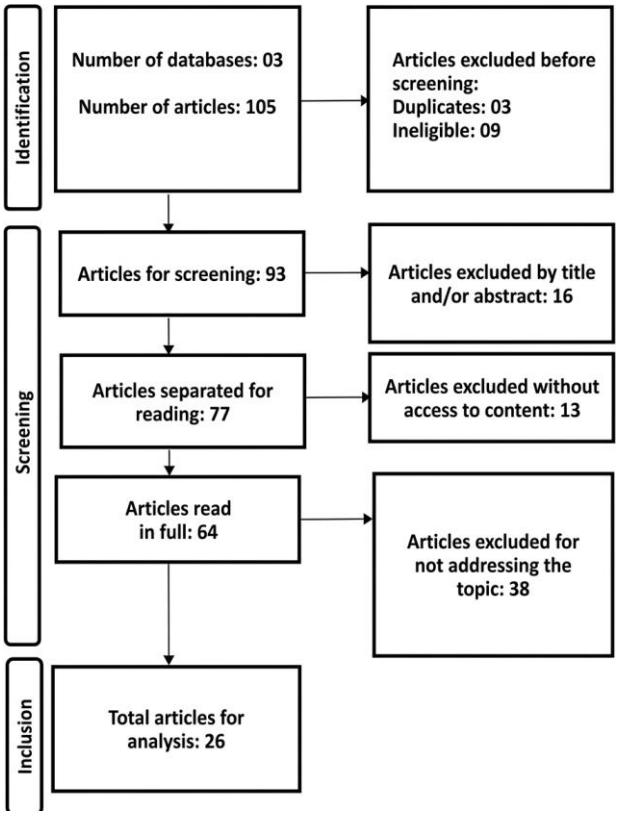
Finally, the works that met all established criteria were included in the review and subjected to qualitative analysis.

The study selection process took place in stages. Initially, the titles and abstracts were read in order to identify relevance to the theme. Next, the previously selected articles were read in full, allowing a more careful analysis of their relevance and contribution to the study. Finally, the works that met all established criteria were included in the review and subjected to qualitative analysis.

In the following paragraph, Figure 2 is presented, illustrating the flowchart of the study selection process, highlighting the stages of identification, screening, eligibility, and inclusion of the articles analyzed in this review.

Figure 2

Flowchart of the study selection process



Source: Authors (2026)

Data analysis was carried out using the content analysis technique, allowing the categorization and interpretation of the findings in a systematic and critical manner. The information extracted from the selected studies was organized into thematic categories, considering aspects such as the contributions of gamification to science education, impacts on meaningful learning, pedagogical strategies used, and limitations identified in the literature.

Thus, the methodology adopted enabled a comprehensive and well-founded analysis of the theme, contributing to the understanding of the impacts of gamification on meaningful learning and offering support for the development of innovative pedagogical practices in Natural Sciences education.

RESULTS AND DISCUSSION

The results of this review show that gamification, when applied to Natural Sciences education, presents significant positive impacts on the teaching-learning process, especially with regard to student engagement, motivation, and the construction of more lasting knowledge. In general, the studies analyzed converge in indicating that the incorporation of playful and interactive elements into the educational context contributes to overcoming traditional practices centered on memorization, favoring more active and participatory approaches (Neto; Penteado; Carvalho, 2023; Curvo; Mello; Leão, 2023).

It is observed that, in Natural Sciences education, gamification has been widely used in subjects such as Biology, Chemistry, and Physics, promoting greater student interest in scientific content. In studies focused on Biology teaching, for example, increased classroom participation and improved understanding of complex concepts stand out, especially when educational games and gamified digital platforms are used (Feliciano et al., 2023; Teixeira; Valle, 2025). In Physics teaching, gamification has contributed to making abstract content more accessible, favoring the contextualization and practical application of knowledge (Silva; Zanelato, 2024; Siqueira et al., 2026). Similarly, in Chemistry teaching, gamified strategies help in understanding theoretical content and stimulate investigative thinking (Pereira; Leite, 2025; Santos et al., 2025).

Another relevant aspect identified in the studies concerns the impact of gamification on the development of cognitive and socioemotional skills. Research indicates that the use of game mechanics, such as progressive challenges, rewards, and immediate feedback, favors the development of critical thinking, autonomy, and self-regulation of learning (Alahmari et al., 2023; Ahmed et al., 2025). In addition, the social interaction promoted by gamified activities contributes to strengthening collaborative skills, which are essential in the contemporary educational context (Santos Rey; Linhares; Borba-Pinheiro, 2025).

In the following paragraph, Table 1 is presented, which synthesizes the main contributions of gamification in Natural Sciences education, as evidenced in the analyzed studies.

Table 1

Main contributions of gamification in Natural Sciences education

Category	Identified contributions	References
Engagement and motivation	Enhances students' active involvement through interactive stimuli, promoting greater interest, continuous participation, and persistence in learning activities	Feliciano *et al.,* 2023; Teixeira; Valle, 2025
Meaningful learning	Favors the anchoring of new knowledge to pre-existing cognitive structures, promoting non-arbitrary assimilation and the construction of lasting meanings	Siqueira *et al.,* 2026; Farias, 2022
Cognitive development	Stimulates higher-order cognitive processes, such as critical thinking, problem-solving, decision-making, and intellectual autonomy in the learning process	Ahmed *et al.,* 2025; Alahmari *et al.,* 2023
Interdisciplinarity	Enables integrated articulation among different areas of the Natural Sciences, favoring a contextualized and systemic understanding of scientific phenomena	Camatta, 2025; Queiroga; Pacheco, 2024
Social interaction	Promotes collaborative dynamics that strengthen socioemotional skills, such as communication, cooperation, empathy, and teamwork	Santos Rey; Linhares; Borba-Pinheiro, 2025
Understanding of content	Facilitates the appropriation of abstract and complex concepts through playful representations, simulations, and contextualized problem situations	Silva; Zanelato, 2024; Pereira; Leite, 2025

Source: Authors (2026)

Data analysis also reveals that gamification has strong potential to promote meaningful learning, especially when articulated with the principles of Ausubel's theory. According to this perspective, learning occurs more effectively when new information is related to students' prior knowledge, allowing structured and non-arbitrary assimilation (Farias, 2022; Costa Júnior et al., 2023). In this sense, gamification acts as a pedagogical mediator that facilitates this connection by making content more attractive and contextualized (Siqueira et al., 2026).

Studies highlight that the use of narratives, missions, and contextualized challenges contributes to the activation of students' prior knowledge, favoring the anchoring of new content in existing cognitive structures (Arcanjo Filho; Martins, 2025). In addition, strategies such as the use of concept maps associated with gamified activities enhance the organization of knowledge, promoting more meaningful learning (Mossi; Vinholi Junior, 2022). Thus, gamification not only increases engagement but also contributes to the quality of learning.

Another important result concerns the interdisciplinarity promoted by gamification. The studies analyzed indicate that this approach allows the integration of different areas of knowledge, favoring a broader and more contextualized understanding of scientific phenomena (Camatta, 2025). The articulation among Biology, Chemistry, and Physics content in gamified activities contributes to the construction of more integrated knowledge, breaking with the traditional fragmentation of teaching (Queiroga; Pacheco, 2024).

In the following paragraph, Table 2 is presented, highlighting the main limitations and challenges associated with the implementation of gamification in Natural Sciences education.

Table 2

Limitations and challenges of gamification in Natural Sciences education

Category	Identified limitations and challenges	References
Pedagogical planning	Requires structured instructional planning and alignment between gamification elements and educational objectives, at the risk of pedagogical mischaracterization	Alahmari *et al.,* 2023
Teacher training	Reveals gaps in teachers' initial and continuing education for the critical and intentional use of active methodologies mediated by technologies	Neto; Penteado; Carvalho, 2023
Technological infrastructure	Depends on the availability and quality of technological resources, whose absence may compromise the effectiveness of gamified strategies	Ateş; Polat, 2025
Superficiality of learning	May induce excessive valorization of playful aspects to the detriment of conceptual depth, resulting in fragmented or weakly consolidated learning	Zourmpakis; Kalogiannakis; Papadakis, 2023
Teacher resistance	Faces barriers related to resistance to pedagogical innovation, often associated with methodological insecurity or with traditional educational culture	Neto; Penteado; Carvalho, 2023
Inequality of access	Reflects disparities in students' access to digital technologies, which may widen educational inequalities and limit equity in the learning process	Alahmari et al., 2023

Source: Authors (2026)

Despite the identified benefits, the literature also points to relevant limitations in the application of gamification. Among the main challenges, the need for adequate pedagogical planning, teacher training for the use of active methodologies, and the availability of technological resources stand out (Zourmpakis; Kalogiannakis; Papadakis, 2023; Ateş; Polat, 2025). In addition, some studies indicate that the inappropriate use of gamification may result in superficiality of learning, especially when there is an excessive focus on playful elements to the detriment of pedagogical objectives (Alahmari et al., 2023).

Another observed aspect concerns the resistance of some teachers to adopting innovative methodologies, which may limit the effectiveness of gamification in the school context. Furthermore, the heterogeneity of classes and differences in access to digital technologies also constitute challenges to the implementation of this approach (Neto; Penteado; Carvalho, 2023).

Finally, the results indicate that gamification, when intentionally planned and aligned with the principles of meaningful learning, has great potential to transform Natural Sciences education. The integration of playful elements, interdisciplinarity, and a consistent theoretical foundation favors the construction of a more dynamic, meaningful, and student-centered educational process. However, its effectiveness depends on factors such as teacher training, pedagogical planning, and adaptation to the educational context, highlighting the need for further research in this area.

The discussion of the findings of this research shows that gamification, as an interdisciplinary pedagogical device, has significant potential to transform Natural Sciences education, especially when articulated with the assumptions of David Ausubel's meaningful learning theory. In this sense, the results will be discussed based on two central axes: (i) contributions of gamification to the promotion of meaningful learning in Natural Sciences education and (ii) challenges and limitations in the implementation of gamification in the educational context.

CONTRIBUTIONS OF GAMIFICATION TO THE PROMOTION OF MEANINGFUL LEARNING IN NATURAL SCIENCES EDUCATION

The analysis of the selected studies makes it possible to state that gamification is configured as an effective pedagogical strategy in promoting meaningful learning, above all because it favors the interaction between new content and students' prior knowledge. In this context, Farias (2022) highlights that meaningful learning occurs when there is a substantial relationship between new knowledge and already existing cognitive structures, enabling non-arbitrary and lasting assimilation. By incorporating

playful and interactive elements, gamification contributes to activating this prior knowledge, creating favorable conditions for the construction of meanings.

Corroborating this perspective, Costa Júnior et al. (2023) emphasize that meaningful learning depends on pedagogical strategies that promote the organization and integration of knowledge, which can be enhanced by active methodologies such as gamification. In this sense, by using challenges, narratives, and progression systems, this approach stimulates students to establish connections between concepts, favoring the construction of more structured knowledge.

In the specific field of Natural Sciences education, Queiroga and Pacheco (2024) demonstrate that gamification contributes to making content more accessible and contextualized, especially in the final years of elementary education. According to the authors, the use of educational games and digital platforms allows scientific concepts to be explored in a more dynamic way, facilitating the understanding of abstract content. Similarly, Silva and Zanelato (2024) highlight that, in Physics teaching, gamification makes possible the visualization of complex phenomena, promoting greater understanding and practical application of knowledge.

In addition, Feliciano et al. (2023) emphasize that gamification favors student engagement, an aspect fundamental to meaningful learning. According to the authors, the increase in intrinsic motivation contributes to greater dedication to the proposed activities, which enhances the assimilation of content. This idea is reinforced by Ahmed et al. (2025), who point out that gamification also stimulates the development of critical thinking by proposing challenges that require analysis, decision-making, and problem-solving.

Another relevant aspect concerns the interdisciplinarity promoted by gamification. Camatta (2025) argues that the integration of different areas of knowledge is essential for the understanding of scientific phenomena, with gamification being an effective tool for promoting this articulation. In this sense, gamified activities allow Biology, Chemistry, and Physics content to be addressed in an integrated manner, favoring a broader and more contextualized view of science.

Siqueira et al. (2026) reinforce this perspective by highlighting that gamification, when applied in an interdisciplinary way, enhances meaningful learning by promoting connections among different areas of knowledge. According to the authors, this approach contributes to the construction of more integrated knowledge that is more applicable to students' reality.

Furthermore, Mossi and Vinholi Junior (2022) emphasize that strategies such as concept maps, when associated with gamification, enhance the organization of knowledge, favoring meaningful learning. This integration among different active methodologies expands pedagogical possibilities, making the teaching process more dynamic and effective.

Finally, Rocha et al. (2026) emphasize that overcoming mechanical learning is one of the main challenges of science education, with gamification being a promising strategy for promoting this transformation. By stimulating students' active participation and the construction of meanings, this approach contributes to the formation of critical and autonomous subjects, aligning with the principles of Ausubel's theory.

CHALLENGES AND LIMITATIONS IN THE IMPLEMENTATION OF GAMIFICATION IN THE EDUCATIONAL CONTEXT

Despite the evidenced contributions, the implementation of gamification in Natural Sciences education faces significant challenges that need to be considered in order to ensure its effectiveness. One of the main aspects concerns the need for adequate pedagogical planning. In this sense, Alahmari et al. (2023) warn that gamification should not be used superficially or decontextualized; alignment between game elements and educational objectives is fundamental.

Neto, Penteado, and Carvalho (2023) reinforce this concern by highlighting that the absence of planning may compromise the quality of the teaching-learning process, resulting in activities that prioritize the playful aspect to the detriment of content. According to the authors, it is necessary for the

teacher to act as a mediator of the process, ensuring that gamification is used intentionally and pedagogically.

Another relevant challenge concerns teacher training. According to Curvo, Mello, and Leão (2023), many teachers still do not feel prepared to use active methodologies, especially those involving digital technologies. This gap in training may limit the adoption of gamification, making its effective implementation more difficult.

In addition, Zourmpakis, Kalogiannakis, and Papadakis (2023) highlight that the inappropriate use of gamification may result in superficiality of learning, especially when there is excessive focus on elements of reward and competition. According to the authors, it is essential that gamification be associated with pedagogical strategies that promote reflection and understanding of content.

Technological infrastructure also presents itself as a limiting factor. Ateş and Polat (2025) point out that the implementation of gamified strategies, especially those using digital technologies, depends on the availability of adequate resources, which is not always the reality in all educational contexts. This limitation may compromise equity in access to innovative methodologies.

Another important aspect concerns inequality in access to digital technologies. Alahmari et al. (2023) highlight that socioeconomic differences among students may impact access to technological resources, making the inclusive implementation of gamification more difficult. This factor reinforces the need to consider the educational context when adopting this methodology.

Additionally, Santos Rey, Linhares, and Borba-Pinheiro (2025) emphasize that resistance on the part of some teachers still constitutes an obstacle to the implementation of gamification. According to the authors, this resistance is often associated with a lack of familiarity with new methodologies and with the predominance of traditional pedagogical practices.

Finally, Pereira and Leite (2024) highlight that, although gamification has the potential to improve learning, its results depend on factors such as students' profile, the educational context, and the way the

methodology is applied. Thus, it becomes evident that gamification should not be seen as a universal solution, but rather as a strategy that needs to be adapted to the specificities of each reality.

In view of this, it is understood that, although gamification presents numerous contributions to Natural Sciences education, its effectiveness depends on a set of factors involving planning, teacher training, infrastructure, and adaptation to the educational context. Thus, overcoming these challenges is fundamental for this methodology to fulfill its transformative potential in the teaching-learning process.

CONCLUSION

This research aimed to analyze the impacts of gamification as an interdisciplinary pedagogical device in Natural Sciences education, in light of David Ausubel's theory of meaningful learning. Throughout the study, an effort was made to understand how this active methodology can contribute to the construction of more lasting and contextualized knowledge, as well as to identify its potentialities and limitations in the contemporary educational context.

In response to the guiding question, the results show that this approach significantly favors learning when used in a planned and intentional manner. Gamification makes possible the activation of prior knowledge, a central element in Ausubelian theory, promoting the anchoring of new information in already existing cognitive structures and, consequently, the construction of consistent and lasting meanings.

With regard to revisiting the objectives, it was found that the general objective was achieved by demonstrating the positive impacts of gamification on the teaching-learning process. The specific objectives were also fulfilled, since it was possible to discuss the foundations of gamification as an active methodology, understand the principles of meaningful learning, analyze empirical evidence in different areas of the Natural Sciences, and identify both the contributions and the limitations of this pedagogical approach.

Among the main results, it stands out that gamification promotes greater engagement, motivation, and active student participation, in addition to favoring the development of cognitive skills such as critical thinking, problem-solving, and autonomy. Moreover, it became evident that the integration of playful elements with theoretically grounded pedagogical strategies contributes to the understanding of complex content, especially when associated with interdisciplinarity, allowing a broader and more contextualized view of scientific phenomena.

The research also showed that gamification acts as an important mediator in the teaching-learning process by making content more accessible and meaningful for students. Its articulation with Ausubel's theory reinforces the importance of pedagogical practices that value prior knowledge and promote active learning, overcoming traditional models based on memorization. In this way, gamification is consolidated as a promising strategy for innovation in Natural Sciences education.

As a contribution, this study broadens discussions on the use of active methodologies in the educational context, offering theoretical and practical support for implementing gamification in a more conscious and well-founded manner. In addition, it highlights the relevance of interdisciplinarity as a central element in the construction of meaningful learning, contributing to the education of students who are more critical, autonomous, and prepared to face contemporary challenges.

Finally, it is suggested that future research takes a more in-depth look at the empirical analysis of gamification in diverse educational contexts, considering variables such as levels of education, different socioeconomic realities, and the use of emerging digital technologies. It is also recommended that investigations explore teacher training for the use of gamified methodologies, as well as longitudinal studies that assess the impacts of this approach on meaningful learning in the long term. In this way, it will be possible to further consolidate the potential of gamification as a transformative tool in Natural Sciences education.

REFERENCES

AHMED, Adedolapo Abdulahi et al. The role of gamification in enhancing critical thinking skills in online science education. Jurnal Saintifik (Multi Science Journal), v. 23, n. 2, p. 73-80, 2025.

ALAHMARI, Muteeb *et al*. Trends and gaps in empirical research on gamification in science education: a systematic review of the literature. Contemporary Educational Technology, v. 15, n. 3, 2023.

ARCANJO FILHO, Miguel; MARTINS, Islane Cristina. Avaliação da influência de metodologias alternativas para gerar aprendizagem significativa no ensino de ciências naturais com base nos conceitos de Ausubel: uma revisão. Revista Inclusiones, v. 12, n. 1, p. 132-146, 2025.

ATEŞ, Hüseyin; POLAT, Merve. Leveraging augmented reality and gamification for enhanced self-regulation in science education. Education and Information Technologies, v. 30, n. 12, p. 17079-17110, 2025.

CAMATTA, Maria de Lourdes Aparecida Novich. Gamificação como metodologia ativa no ensino de ciências. Lumen et Virtus, v. 16, n. 47, p. 3093-3107, 2025.

COSTA JÚNIOR, J. F. *et al*. Um olhar pedagógico sobre a aprendizagem significativa de David Ausubel. REBENA - Revista Brasileira de Ensino e Aprendizagem, v. 5, p. 51-68, 2023.

CURVO, E. F.; MELLO, G. J.; LEÃO, M. F. A gamificação como prática de ensino inovadora: um olhar para as teorias epistemológicas. Cuadernos de Educación y Desarrollo, v. 15, n. 6, p. 4972-4994, 2023.

FARIAS, G. B. de. Contributos da aprendizagem significativa de David Ausubel para o desenvolvimento da competência em informação. Perspectivas em Ciência da Informação, v. 27, n. 2, p. 58-76, 2022.

FELICIANO, S. M. *et al.* Gamificação como alternativa para processo de aprendizagem na disciplina de biologia. Revista Ibero-Americana de Humanidades, Ciências e Educação, v. 9, n. 8, p. 1359-1369, 2023.

GAUDÊNCIO, Jéssica S. *et al.* Teorias de aprendizagem no ensino de Química: uma revisão de literatura a partir de artigos da revista Química Nova na Escola (QNEsc). Química Nova na Escola, v. 45, n. 2, 2023.

MOSSI, Caroline Silverio; VINHOLI JUNIOR, Airton José. The use of concept as meaningful learning strategy in teaching chemistry. Acta Scientiarum Education, v. 44, e53210, 2022.

NETO, Luiz Torres Raposo; PENTEADO, Camila de Fátima de Oliveira; CARVALHO, Lílian Amaral. Gamificação como ferramenta para o processo de ensino e aprendizagem: uma revisão integrativa. Perspectivas em Diálogo: Revista de Educação e Sociedade, v. 10, n. 22, p. 313-327, 2023.

NURHASANAH, Andi *et al.* Improving elementary school students' understanding of the concept through meaningful learning in David Ausubel's perspective. Jurnal Basicedu, v. 6, n. 4, p. 5728-5734, 2022.

PAPADAKIS, Stamatios; ZOURMPAKIS, Alkinoos-Ioannis; KALOGIANNAKIS, Michail. Analyzing the impact of a gamification approach on primary students' motivation and learning in science education. In: International Conference on Interactive Collaborative Learning. Cham: Springer, 2022. p. 701-711.

PEREIRA, Jocimario Alves; LEITE, Bruno Silva. Tendências de pesquisas: uma revisão de artigos sobre gamificação aplicada no ensino de Química. Revista Electrónica de Investigación en Educación en Ciencias, v. 19, n. 2, p. 1-12, 2024.

PEREIRA, J. A.; LEITE, B. S. Gamificação no ensino de Química: o que dizem e pensam os estudantes do Ensino Médio? Cuadernos de Educación y Desarrollo, v. 17, n. 10, e9539, 2025.

QUEIROGA, M. P.; PACHECO, C. S. G. R. A gamificação no ensino de ciências biológicas: sistemática nos anos finais do ensino fundamental. Cadernos Cajuína, v. 9, n. 6, e249643, 2024.

ROCHA, Bruno Pinheiro *et al.* Da memorização ao significado: contribuições da teoria de Ausubel para a transformação do ensino de Física. Revista Tópicos, v. 4, n. 31, p. 1-16, 2026.

SANTOS, Wesclle Johnson Mota et al. Ensino de Química com atividades lúdicas aplicadas com alunos do ensino médio. Aurum Editora, p. 355-365, 2025.

SANTOS REY, Agersonias; LINHARES, Diego Gama; BORBA-PINHEIRO, Claudio Joaquim. A gamificação como metodologia ativa na educação física escolar: revisão sistemática de estudos qualitativos. Cuerpo, Cultura y Movimiento, v. 15, n. 1, p. 147-160, 2025.

SEXTON, S. S. Meaningful learning—David P. Ausubel. In: AKPAN, B.; KENNEDY, T. J. (org.). Science Education in Theory and Practice. Cham: Springer, 2025.

SIQUEIRA, T. F. da S. *et al.* Perspectivas da gamificação na construção de uma aprendizagem significativa: uma abordagem interdisciplinar no ensino de Física. Revista OWL, v. 4, n. 2, p. 1-21, 2026.

SILVA, F. L. da; ZANELATO, A. I. Ensino de Física através da gamificação. Revista Contemporânea, v. 4, n. 8, e5386, 2024.

TEIXEIRA, A. R. L.; VALLE, M. G. do. Panorama do uso da metodologia da gamificação no ensino de biologia: uma revisão sistemática da literatura. Cuadernos de Educación y Desarrollo, v. 17, n. 1, e7397, 2025.

ZARROR, Afif Fauzan; SUMARYATI, Sri; SUKMAWATI, Fatma. Transforming science education through gamification: a systematic analysis of trends, impacts, and implications. In: Proceeding of International Conference on Biology Education, Natural Science, and Technology. 2025. p. 134-145.

ZOURMPAKIS, Alkinoos-Ioannis; KALOGIANNAKIS, Michail; PAPADAKIS, Stamatios. Adaptive gamification in science education: an analysis of the impact of implementation and adapted game elements on students' motivation. Computers, v. 12, n. 7, p. 143, 2023.