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Revisão Integrativa

EXPLORING THE IMPACT OF ACTIVE METHODOLOGIES IN TEACHING NATURAL SCIENCES AND THEIR IMPLICATIONS FOR MEANINGFUL LEARNING: AN INTEGRATIVE REVIEW ON INNOVATIVE STRATEGIES IN SCIENCE EDUCATION

EXPLORANDO O IMPACTO DAS METODOLOGIAS ATIVAS NO ENSINO DE CIÊNCIAS DA NATUREZA E SUAS IMPLICAÇÕES PARA A APRENDIZAGEM SIGNIFICATIVA: UMA REVISÃO INTEGRATIVA SOBRE ESTRATÉGIAS INOVADORAS NA EDUCAÇÃO CIENTÍFICA

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RESUMO

Introdução: A adoção de metodologias ativas e recursos didáticos inovadores pode transformar o ensino de Ciências da Natureza, tornando-o mais dinâmico e acessível. No entanto, desafios como a descontextualização e a abstração dos conteúdos dificultam a aprendizagem dos estudantes. **Objetivo**: Diante disso, este estudo realizou uma revisão integrativa da literatura com o objetivo de identificar e analisar as principais estratégias didáticas que promovem a aprendizagem significativa no ensino de Biologia, Física e Química. **Métodos:** A pesquisa foi conduzida nas bases Google Acadêmico, Scientific Electronic Library Online (SciELO) e Periódicos CAPES, entre janeiro e fevereiro de 2025, utilizando critérios de inclusão e exclusão previamente estabelecidos. **Resultados**: Foram selecionados e analisados dezessete (17) artigos publicados no

período de 2020 a 2024. A pesquisa destacou que metodologias ativas, como gamificação, Aprendizagem Baseada em Projetos (ABP) e Sala de Aula Invertida (SAI), são essenciais para o ensino de Ciências da Natureza, pois promovem maior engajamento, autonomia e compreensão dos conceitos. Além disso, estratégias inclusivas permitem a adaptação do ensino a diferentes perfis de aprendizagem, tornando a sala de aula mais interativa e equitativa. **Conclusões**: A pesquisa enfatizou a importância de uma abordagem pedagógica que integre planejamento, execução, avaliação e reflexão contínua para potencializar a aprendizagem e o engajamento dos alunos.

Descritores: Ensino de Ciências da Natureza; Metodologias Ativas; Recursos Didáticos; Aprendizagem Significativa.

ABSTRACT

Introduction: Adopting active methodologies and innovative teaching resources can transform the teaching of Natural Sciences, making it more dynamic and accessible. However, challenges such as decontextualization and content abstraction hinder students' learning. **Objective:** This study conducted an integrative literature review to identify and analyze the main teaching strategies that promote meaningful learning in the teaching of Biology, Physics, and Chemistry. **Methods:** The research was conducted in the databases Google Scholar, Scientific Electronic Library Online (SciELO), and CAPES Periodicals, between January and February 2025, using predefined inclusion and exclusion criteria. **Results:** Seventeen (17) articles published between 2020 and 2024 were selected and analyzed. The study highlighted that active methodologies such as gamification, Project-Based Learning (PBL), and Flipped Classroom (FC), are essential for teaching Natural Sciences, as they promote greater engagement, autonomy, and understanding of concepts. Furthermore, inclusive strategies allow the adaptation of teaching to different learning profiles, making the classroom more interactive and equitable. **Conclusions:** The research emphasized the importance of a pedagogical approach that integrates planning, execution, evaluation, and continuous reflection to enhance learning and student engagement.

Descriptors: *Teaching of Natural Sciences; Active Methodologies; Teaching Resources; Meaningful Learning.*

INTRODUCTION

To keep pace with the constant changes in the world, education plays an essential role in equipping students not only with new knowledge but also with skills that prepare them for the challenges of modern society[1] . Brazilian education has undergone curricular changes, restructuring secondary education to make it more dynamic and aligned with current demands, offering educational pathways that meet students' interests and prepare them for future challenges [2] .

Teaching still largely follows a traditional model based on lectures, in which content is simply transmitted to students. This format fails to account for the demands of a technological society, making learning more challenging because the content is often perceived as complex, extensive, and abstract[3] .

In the field of Natural Sciences, integrating Biology, Physics, and Chemistry poses significant challenges for students, especially when using traditional teaching approaches. Many students have difficulty understanding the content, especially when they are unable to connect it to practical applications. However, not all curriculum topics allow for direct experimentation, which can hinder learning[2] .

Education as a whole is undergoing a challenging phase of transition in its training models. This scenario calls for a reexamination of the various elements that constitute the teaching of Natural Sciences, including the roles of teachers and students, assessment methods, content selection and pedagogical approaches, learning activities, technological tools, and instructional methodologies. Within this framework, methodologies assume a central role, particularly those that promote active student participation, meaningful learning, collaboration, and the development of learner autonomy [4] .

Within this context, it is essential that teachers conduct the teaching process by incorporating active methodologies that encourage active student participation, allowing them to become more directly involved in the construction of knowledge, a fundamental aspect [5]. By active methodologies, we mean a set of methods, techniques, and strategies teachers use to transform teaching into a dynamic process in which students take a central role. These approaches seek to stimulate active participation, knowledge construction, and skill development, making learning more meaningful and engaging [4] .

In this sense, Active Methodologies stand out as an innovative approach, making teaching more dynamic and promoting more engaging and meaningful learning through interactive strategies in the classroom[1] .

Active Methodologies in Natural Sciences make teaching more dynamic and participatory, stimulating knowledge construction, problem solving, and collaborative debate[2] . Active learning occurs when students formulate questions, test and adjust their mental models, making the process more meaningful[6] . This approach differs in its classroom practice, enabling students to relate the content to everyday situations, making it more engaging[1] .

Based on the above, this study conducted an integrative literature review to identify and analyze the main teaching strategies that promote meaningful learning in Biology, Physics, and Chemistry, focusing on active methodologies and innovative resources that enhance student engagement and understanding.

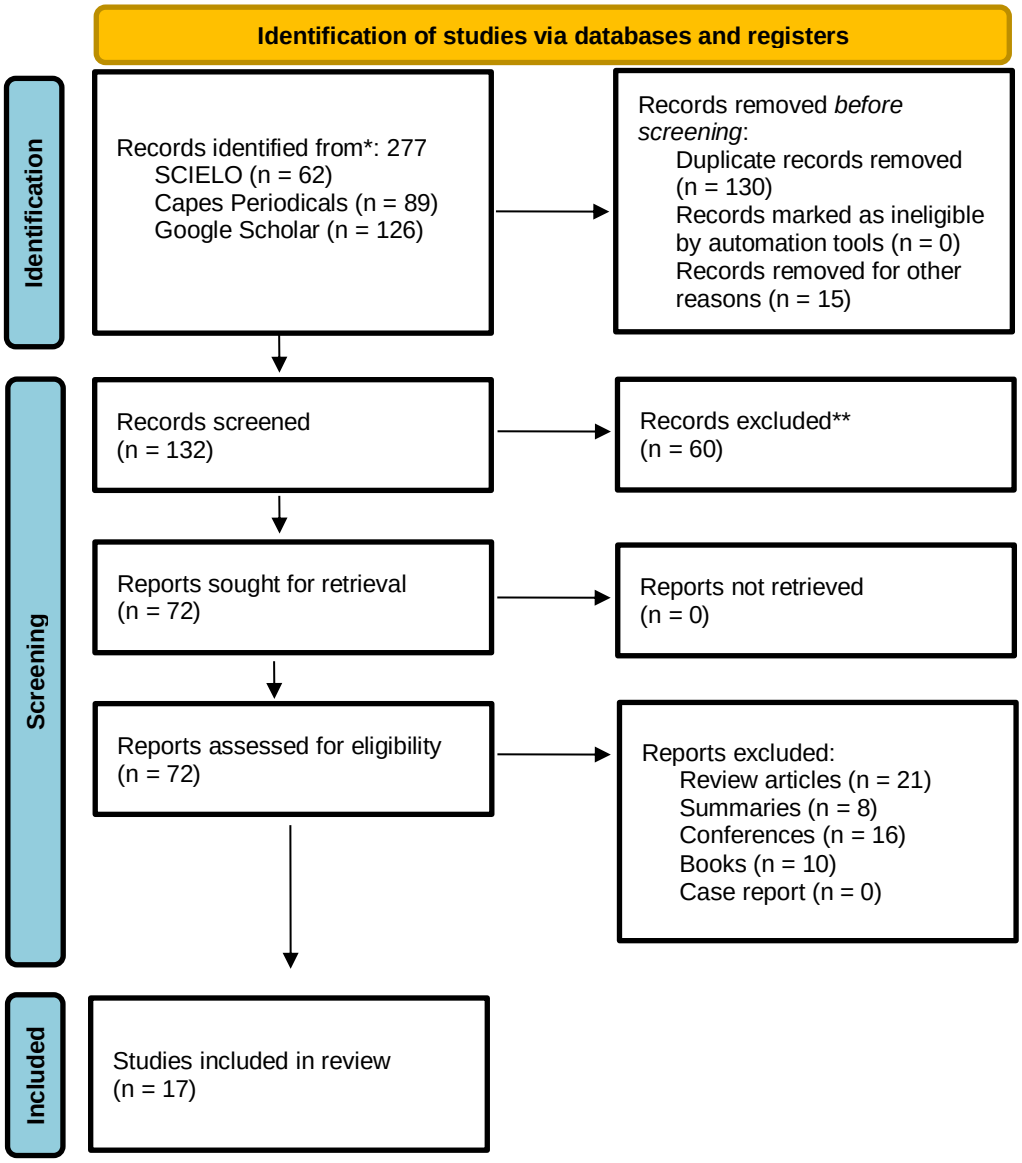
METHODOLOGY

With the aim of mapping and evaluating academic production on the use of Active Methodologies in the teaching of natural sciences developed in the country, a research modality called "state of the art" was adopted, through an integrative review. A qualitative approach was used to analyze the information found, focusing on the nature of the identified productions, their general characteristics, and the trends observed in publications on the topic.

The integrative review is the most comprehensive methodological approach among the types of review, as it allows the inclusion of experimental and non-experimental studies to achieve a complete understanding of the phenomenon under analysis. It combines data from theoretical and empirical literature, incorporating a variety of objectives, such as defining concepts, reviewing theories and evidence, and analyzing methodological issues related to a specific topic. The diversity of the sample and the multiplicity of approaches aim to generate a consistent and clear understanding of complex concepts, theories, or problems[7].

To guide the integrative review, the following guiding question was formulated: How can the use of different active teaching methodologies improve the teaching of natural science subjects in the school context? The search was conducted across electronic databases of scientific journals, including Google Scholar, Scientific Electronic Library Online (SciELO), and the Capes Journal Portal. The analysis period covered the last five years, from 2020 to 2024, and scientific articles in Portuguese were selected that evaluated successful educational practices, highlighting the results for educators, students, and other participants in the educational processes. The following keywords were used in the search tools: teaching, active methodologies, didactic innovation, teaching materials, and science education. During the review process, unreliable publications such as drafts, website articles, preprints of submitted manuscripts, scientific reports, and conference proceedings were excluded. In total, this study included 17 publications: 10 from Google Scholar, 3 from the Scientific Electronic Library Online (SciELO), and 4 from the Capes Journal Portal (Figure 1).

Figure 1 - Flowchart of the integrative review on the use of active methodologies in teaching



Flowchart template available at www.prisma-statement.org/prismastatement/flowdiagram.aspx

As mentioned, the selection criteria for publications were based on the authors' abstracts, with an emphasis on the didactic intentions underlying the work. Thus, publications that mentioned the use of teaching materials in the title or abstract were selected, understanding that this reference indicated the authors' intention to highlight the role of active methodologies in teaching natural sciences. Upon noting that the didactic function was emphasized in all studies, we sought to identify specific references to the use of these materials in the publications. Studies

that justified their proposals by linking teaching strategies to the use of teaching materials were also included.

Exclusion criteria included incomplete articles, books, and undergraduate monographs. In addition, to ensure the diversity of contributions, works that presented methods and results involving very similar teaching resources were excluded.

RESULTS AND DISCUSSIONS

In this section, the teaching materials identified in the studies selected for this integrative review were analyzed, with a focus on active methodologies. Table 1 presents an overview of the reviewed studies, organized according to author and year of publication, objectives and subjects covered, teaching resources used, and the main results and conclusions of the articles.

This structure allows for a detailed analysis of the pedagogical approaches adopted over the years, enabling the identification of trends and the comparison of the application of different teaching strategies. In addition, the table offers insights into the effectiveness of each resource in the educational process, highlighting its impact on learning. Thus, the organization of the studies contributes to a better understanding of the role of active methodologies in education and to the improvement of pedagogical practices.

Table 1- Distribution of studies on educational activities using different teaching resources, according to study identification, year of publication, type of resource used and results.

Author and year of publication	Objectives and Topics Covered	Teaching resources	Main results and conclusions
Almeida Neto and Gonçalves, 2024 [8]	Chemistry; Integrate Chemistry and Physical Education through a game that uses active learning to increase student engagement and understanding.	The teaching resources for the 'Chemistry in Motion' game include question cards, a board, experiment kits, simulation apps and educational videos, promoting practical and collaborative learning between Chemistry and Physical Education.	The 'Chemistry in Motion' game effectively integrated Chemistry and Physical Education, stimulating student engagement, the development of cognitive and motor skills, and promoting teamwork.
Bezerra and Silva e Mello, 2024 [9]	Biology; To understand whether undergraduate students in Biological Sciences at the State University of Rio de Janeiro	Teaching resources for virtual gamification in Biology teaching include platforms such as Kahoot , PhET simulations and educational games,	Virtual gamification in Biology teaching increased student engagement, improved understanding of concepts, and allowed future teachers to integrate educational technologies into

	(UERJ/Maracanã) understand the pedagogical and inclusive potential of virtual gamification.	as well as gamified guides and lesson plans , promoting dynamic and interactive learning.	their pedagogical practices.
Nepomuceno et al., 2024 [10]	Sciences; Present the pedagogical experience experienced in teaching Environmental Education through Project-Based Learning, in order to encourage reflections on the topic.	Implementation of ten-step activities, including environmental problem-solving, storytelling, debates, project development and implementation, and theoretical and reflective classes. The activities took place remotely and later in person, supported by virtual platforms.	The implementation of PBL in Environmental Education has proven effective in promoting awareness, protagonism and reflection among students on environmental problems, contributing to the formation of multipliers of preservation and sustainability.
Magalhães *et al* ., 2023 [11]	Chemistry; Produce and apply a board game representing a dye-sensitized solar cell (CSS) as a teaching resource in approaching the content of energy conversion.	Based on the theoretical foundations of dye-sensitized solar cells discussed previously, an educational game was developed that considers level 3 of interaction between game and player, in the format of a closed and tilted board, inspired by the Arcade Pinball game model.	The game provided an easy-to-understand visualization of how the energy conversion process is performed by a dye-sensitized solar cell (DSSC). It was presented during the "Café com Ciência" science outreach event, hosted by the Federal University of São João del Rei, and achieved positive results both in terms of gameplay and in helping students understand the topic. Feedback suggests that the game can be a useful tool for students and educators, achieving its full educational potential and facilitating the learning of complex concepts.
Almeida *et al* ., 2022 [12]	Chemistry: Analyze the contributions of a Didactic Sequence in the learning process of inorganic acids content for students in rural areas.	A teaching sequence on inorganic acids was developed, consisting of 10 lessons. The sequence included a diagnostic questionnaire, written activities, a practical activity, and a knowledge game. The teaching sequence began with a discussion circle on bean cultivation, followed by an acid rain experiment, and finally, the use of the Knowledge Game. The approach aimed to integrate dialogue, practice, and games to explore the content in an interactive and contextualized way.	The research revealed that the Teaching Sequence on Functions of Inorganic Acids increased student interest, demonstrating motivation and approval of the proposal. The activities facilitated knowledge production and helped students make decisions for citizenship. Students responded well to the conceptual questions, indicating that the methodology fostered collective learning, fostering the connection between theory and practice.

Viana and Da Silva, 2022 [13]	Biology: Apply tutorial sessions using the Problem-Based Learning (PBL) method in teaching genetics in basic education at a rural public school in the municipality of Abaetetuba, PA.	The PBL methodology was implemented through games, teaching models, pedigrees, and discussion groups, promoting dynamic and interdisciplinary learning, with assessment carried out through questionnaires and group feedback.	The teaching of genetics in basic education, based on the PBL method, promoted the deepening of concepts, the development of research skills and teamwork, integrating Biology, Chemistry, Mathematics and Ethics in a practical and interdisciplinary way.
Dos Anjos et al., 2022 [14]	Physics: Gamify Thermodynamics teaching to increase engagement and promote hands-on, interdisciplinary learning.	Teaching resources such as digital games, interactive quizzes, simulations, gamified hands-on activities , and gamification platforms can transform thermodynamics teaching into an engaging experience, facilitating the understanding of complex concepts and increasing student engagement.	Gamification in the teaching of Thermodynamics has proven effective in increasing student engagement, facilitating the understanding of complex concepts, and promoting active and collaborative learning, making the teaching process more dynamic and meaningful.
Jesus, 2022 [15]	Physics: Assess the impact of the Flipped Classroom on Physics learning, identify its benefits and challenges, and analyze the role of the teacher in mediating the teaching-learning process.	questionnaires, written and audiovisual materials made available on Google Classroom , concept maps created with Popplet , dynamic student presentations, questionnaires and teacher interventions for feedback and assessment.	The Flipped Classroom in Physics teaching increased student engagement and autonomy, but presented challenges related to adapting to the new format and the need for continuous support from teachers.
Rizzo, 2022 [16]	Physics: The use of Project-Based Learning (PBL) in teaching Physics, through the creation of a website, promotes interdisciplinarity, technological development and applied understanding of Acoustics.	The creation of a Project-Based Learning website for teaching Acoustics integrates digital, audiovisual and experimental resources, promoting interactive and interdisciplinary learning.	The creation of a website about teaching Acoustics promoted engagement, interdisciplinarity and meaningful learning, integrating technology and experimentation to facilitate the understanding of concepts.
Estevam *et al* ., 2021 [17]	Science: Develop and evaluate a mobile application for teaching environmental science.	The Environmental Quiz app was developed using the APPY PIE mobile app creation platform, which enables solutions compatible with Android, iOS, Windows Phone, and BlackBerry platforms. This platform is designed to support users with or without programming experience.	Both students and teachers were observed to be engaged and participatory during activities involving this tool. The results demonstrated that the proposed software can be an ally in the knowledge-building process in environmental chemistry teaching.

Conrado et al., 2021 [18]	Sciences: Promotes the integration of Biology, Chemistry, Physics and Ecology, applying concepts of sustainability and teamwork.	Educational resources for the nitrogen cycle through the simulation of an aquaponic system include simulators, chemical test kits, educational videos, and the construction of real aquaponic systems , promoting practical and interdisciplinary learning.	Project-based learning in teaching the nitrogen cycle through the simulation of an aquaponic system promoted interdisciplinary understanding, the development of practical skills, and engagement in sustainable learning.
Batista et al., 2021 [19]	Physics: Carry out an analysis of the strategy for solving open problems with a focus on Meaningful Learning and the Theory of Conceptual Fields.	Questionnaires, dialogic classes, surveys, problem-solving and debates were used to encourage students' autonomy, reflection and active participation.	Initially, students struggled to distinguish between classical and contemporary physics, as well as misconceptions about energy quantization and the photoelectric effect, but they restructured their ideas after discussion. Meaningful learning requires reorganizing prior concepts and is facilitated by problem-solving and debate.
Santos et al., 2021 [20]	Biology: Analyze the contribution of applying the gamification methodology in the teaching-learning process through a bingo-type game.	Bingo, as a teaching resource in Biology, uses personalized cards, digital platforms, and visual materials to make learning more interactive, promoting active student participation.	The use of bingo as a gamification resource in Biology teaching has proven effective in increasing student engagement, facilitating concept retention, and fostering a collaborative learning environment, being an innovative strategy that can be adapted to different educational contexts.
Santos *et al* ., 2021 [21]	Chemistry: Describe and analyze the application of a playful activity in the classroom – the didactic-pedagogical game “Chemical Checkers”.	The application of a playful activity in the classroom, the didactic-pedagogical game “Chemical Checkers”, was developed by students of the undergraduate course in Biological Sciences at the State University of Bahia and the Institutional Program of Scholarships for Teaching Initiation (PIBID).	The game facilitated student learning and was considered an excellent alternative to assist/complement chemistry teaching. Due to its low cost and ease of construction, it was considered a viable option for making Science/Chemistry classes more dynamic. Furthermore, this experience helped future teachers recognize their potential in developing their personal and professional skills, encouraging them to take on new challenges when adapting new games.
Da Silva et al., 2021 [22]	Chemistry: Promote student autonomy, develop	The teaching resources included videos, animations, audio, slides,	The Flipped Classroom approach to

	critical thinking skills, and facilitate understanding of complex concepts such as reactions and molecular structures.	articles, and exercise lists, all available on digital platforms to enhance student engagement. The methodology involved face-to-face discussions and questionnaires and interviews to assess acceptance of the teaching strategy.	teaching Organic Chemistry increased understanding of concepts, promoted greater student participation and autonomy, and improved academic performance, demonstrating an effective learning strategy.
Elias and Gonçalo, 2020 [23]	Biology: Analyze the impact of the Flipped Classroom on biology teaching, aiming to optimize -class time for practical activities and problem-solving in a construction technical course class.	pre --class, texts, editorial cartoons and video lessons were provided in advance, followed by in-person sessions with content review, exercise resolution, discussions and problem analysis.	The evaluation was conducted through an anonymous questionnaire. The Flipped Classroom in Biology teaching increased student engagement, deepened conceptual understanding, and fostered the development of critical thinking and collaboration skills, fostering a more dynamic and interactive learning experience.
Da Silva and De Moura, 2020 [24]	Chemistry: Analyze students' perceptions of the Flipped Classroom in Chemistry teaching, assess its limitations, and explore learning possibilities by addressing both pedagogical aspects and the challenges encountered by students.	Chalkboards, poster boards, posters, slides, data projectors, apps, and -student-led activities were used for the presentations. Additionally, quizzes and questionnaires were used to assess learning, focusing on understanding complex topics such as stoichiometry.	The Flipped Classroom in Chemistry teaching increased student engagement and facilitated active learning, although it presented challenges related to student autonomy and the need for greater teacher support.

Source: Prepared by the authors (2025).

From the articles in Table 1, it was evident that integrating different disciplines through active methodologies, such as gamification, Project-Based Learning (PBL), and Flipped Classroom (FCL), demonstrated significant potential to increase student engagement and understanding, as evidenced by the studies presented. In Chemistry, for example, the application of games and educational resources, such as board games and gamification, has proven highly effective in fostering understanding of complex concepts, such as chemical reactions and energy conversion. In Biology, the use of virtual gamification in genetics teaching and the analysis of its pedagogical and inclusive potential contribute to more dynamic and collaborative learning.

PBL, when applied to Environmental Education and Physics teaching, promotes interdisciplinary development, integrating different areas of knowledge and encouraging critical reflection. Implementing the Flipped Classroom has also proven effective in both Physics and Biology, optimizing class time and facilitating hands-on activities and problem-solving, thus providing students with opportunities for autonomy. Thus, these methodologies have the power to transform pedagogical practice, offering students opportunities for more active, interactive, and meaningful learning.

The teaching resources across the different methodologies combine digital and traditional tools, focusing on interactivity and student engagement. The game "Chemistry in Motion," for example, uses question cards, a board game, experiment kits, and simulation apps, promoting hands-on and collaborative learning. In Biology teaching, gamification is enhanced by platforms such as Kahoot and PhET. Simulations, gamified guides, and lesson plans create a dynamic learning environment. Educational games, quizzes, hands-on activities, and discussion groups were developed to teach topics such as dye-sensitized solar cells and inorganic acids, effectively integrating theory and practice in a contextualized way.

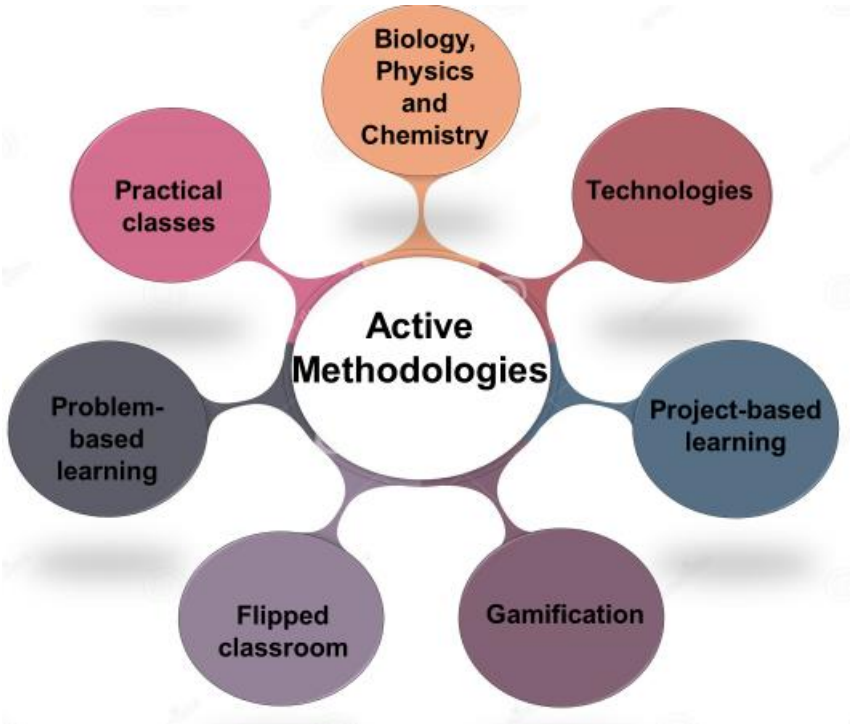
The PBL methodology, when applied to genetics teaching, also used games, teaching models, and roundtables to promote interdisciplinarity. In thermodynamics teaching, resources such as interactive quizzes, simulations, and gamification platforms made learning more engaging and understandable. Furthermore, creating concept maps with tools such as Popplet, using mobile apps like Environmental Quiz, and implementing real aquaponic systems to simulate the nitrogen cycle are examples of how digital and practical resources can be applied to make teaching more effective and interactive. The diversity of these resources, including videos, bingo games, classroom dynamics, and website-building platforms, illustrates how integrating technologies and innovative approaches enriches the educational experience, making it more accessible and participatory.

The results and conclusions show that innovative approaches such as games, gamification, and active methodologies were effective in teaching various subjects. The "Chemistry in Motion" game integrated Chemistry and Physical Education, promoting cognitive and motor skills. Gamification in Biology and other subjects increased student engagement, improved conceptual understanding, and empowered future teachers. PBL in Environmental Education encouraged student awareness and proactive participation. Tools such as the dye-sensitized solar

cell game and the teaching sequence on inorganic acids facilitated the understanding of complex concepts. The PBL methodology and the Flipped Classroom promoted interdisciplinary learning, increased student autonomy, and participation, despite some challenges. Educational games such as "Chemical Checkers " provided effective, low-cost alternatives that enriched the teaching process.

Figure 2 presents a multidimensional approach to active teaching methodologies, as discussed in Table 1, highlighting their application in Biology, Physics, and Chemistry. These methodologies include hands-on classes, educational technologies, gamification, project-based and problem-based learning, and the flipped classroom. These approaches promote more meaningful and engaging learning, encouraging active student participation and stimulating knowledge construction. By integrating diverse resources and strategies, teaching becomes more dynamic, fostering the development of autonomy, critical reflection, and connections between theory and practice in the educational context.

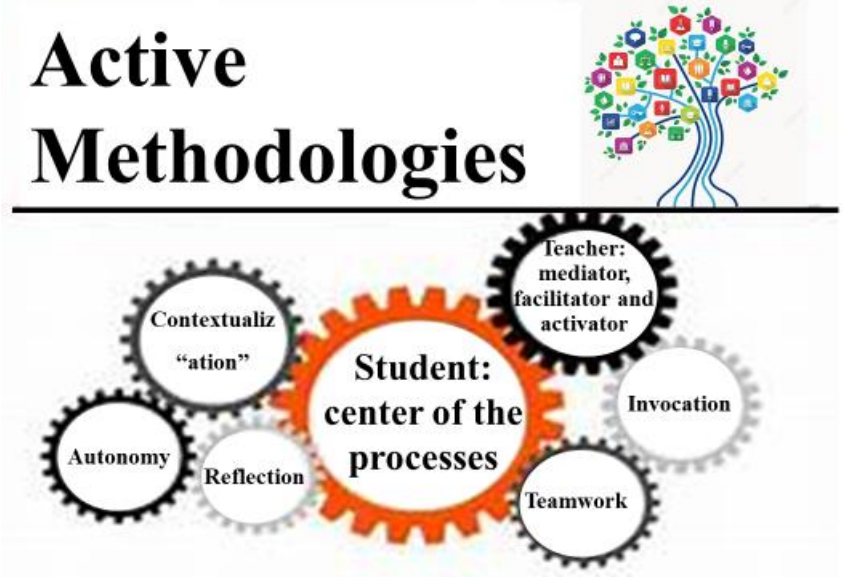
Figure 2 – Active methodologies in teaching: a multidimensional approach to enrich the educational process



Source: Prepared by the authors (2025).

Figure 3 highlights the essential elements of active methodologies in the learning process, emphasizing the student as the center of instruction. In this context, the teacher assumes the role of mediator, facilitator, and activator of knowledge, encouraging autonomy, reflection, and contextualization of learning. Furthermore, aspects such as innovation and teamwork are fundamental to making learning more dynamic and meaningful. The integration of these elements promotes more interactive and effective teaching, fostering the development of essential skills.

Figure 3 – Essential Elements of Active Methodologies in the Learning Process



Source: Prepared by the authors (2025) .

In short, active methodologies have proven to be powerful tools for transforming the educational environment, promoting more engaging, dynamic, and student-centered learning. By integrating approaches such as games, gamification, project-based learning, and other innovative strategies, it is possible to foster students' autonomy, critical thinking, and collaborative work. These methodologies not only facilitate the understanding of complex concepts but also encourage active participation and the development of essential skills for developing critical citizens prepared to face the challenges of the contemporary world. With appropriate adaptation and application, active methodologies can enrich teaching and provide more meaningful learning experiences.

CONCLUSIONS

This integrative review aimed to map and evaluate academic literature on the use of active methodologies in Natural Sciences teaching in Brazil, focusing on publications from 2020 to 2024. The main methodologies discussed demonstrate a positive impact on student learning, promoting greater engagement, autonomy, and understanding of complex concepts. In Chemistry, educational games and gamification were effective in explaining topics such as chemical reactions and energy conversion. In Biology, virtual gamification and the use of technologies such as Kahoot improved the teaching of genetics. PBL and the Flipped Classroom proved effective in promoting interdisciplinary learning and collaborative practices, especially in Environmental and Physical Education.

Teaching resources, both digital and traditional, such as games, quizzes, simulations, and gamification platforms, have proven effective in teaching diverse content, facilitating student understanding and encouraging active participation. The use of active methodologies has been identified as an effective strategy for transforming pedagogical practice, making education more dynamic and meaningful.

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