

## Research articles

# Anime and science: meaningful learning with Dr. Stone in High School

## Anime e ciência: aprendizagem significativa com Dr. Stone no Ensino Médio

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**HOW TO CITE:** FREITAS, B. F.; XAVIER-SANTOS, S. Anime and science: meaningful learning with Dr. Stone in High School. *Revista Ibero-Americana de Estudos em Educação*, Araraquara, v. 21, e19914, 2026. e-ISSN: 1982-5587. DOI: <https://doi.org/10.21723/riaee.v21i00.1991402>

### Abstract

This study examines the use of the anime *Dr. Stone* as a pedagogical resource to support meaningful learning of the scientific method, grounded in David Ausubel's Theory of Meaningful Learning. A Potentially Meaningful Teaching Unit (PMTU) was designed and implemented, structured into four stages: assessment of prior knowledge, use of an advance organizer, practical activities, and evaluation. The qualitative and applied research was conducted in a public high school in a municipality in the interior of Goiás, Brazil, involving students from the third year of secondary education. The results indicate that the use of the anime as an advance organizer contributed to students' understanding of the stages of the scientific method by articulating audiovisual narratives with experimental practices. Although difficulties were identified in the elaboration of critical responses in individual assessment activities, the incorporation of elements of popular culture favored student engagement and the contextualization of scientific content. The study highlights the role of popular culture as a mediating resource in science education and points to the need for adjustments in assessment strategies to foster greater student autonomy and conceptual elaboration.

**Keywords:** science teaching; PMTU; pop culture.

### Resumo

Este estudo analisa o uso do anime *Dr. Stone* como recurso didático para favorecer a aprendizagem significativa do método científico, à luz da Teoria da Aprendizagem Significativa de David Ausubel. Foi desenvolvida e aplicada uma Unidade de Ensino Potencialmente Significativa (UEPS), estruturada em quatro etapas: levantamento de conhecimentos prévios, utilização de organizador prévio, atividades práticas e avaliação. A pesquisa, de natureza qualitativa e aplicada, foi realizada em uma escola pública de um município do interior de Goiás, Brasil, com estudantes da 3ª série do Ensino Médio. Os resultados indicam que o uso do anime como organizador prévio contribuiu para a compreensão das etapas do método científico, ao articular narrativas audiovisuais a práticas experimentais. Embora tenham sido identificadas dificuldades na elaboração de respostas críticas em atividades avaliativas individuais, a inserção de elementos da cultura pop favoreceu o engajamento dos estudantes e a contextualização dos conteúdos científicos. O estudo evidencia o papel da cultura pop como recurso mediador no ensino de Ciências e aponta a necessidade de ajustes nas estratégias avaliativas para ampliar a autonomia e a elaboração conceitual dos estudantes.

**Palavras-chave:** ensino de ciências; UEPS; cultura pop.

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**Submitted:** December 20, 2024

**Reviewed:** February 17, 2026

**Approved:** February 19, 2026

### Financial support:

nothing to declare.

### Conflicts of interest:

There are no conflicts of interest.

### Ethics committee approval:

CAAE 76827523.0.0000.8113.

### Data availability:

Research data are available upon request only.

Study conducted at Universidade Estadual de Goiás (UEG), Anápolis, GO, Brasil.

## INTRODUCTION

Despite technological and scientific advances, traditional teaching practices still predominate in the school context, mainly supported by oral presentations focused on information transmission by the teacher. By prioritizing verbal and written communication and the use of basic tools such as blackboards and notebooks, this approach tends to restrict students to the role of passive knowledge recipients (Camargo; Daros, 2018). Even with the occasional inclusion of audiovisual resources, the pedagogical logic remains oriented towards exam



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preparation and content memorization, to the detriment of building critical and meaningful understanding (Masini; Moreira, 2017). As a consequence, students are poorly prepared to apply knowledge in real contexts or to reflect on the role of science in society.

In light of these limitations, theoretical proposals emerge which seek to overcome mechanical teaching and promote more lasting and contextualized learning. In this scenario, David Ausubel (1978) proposed the Theory of Meaningful Learning, according to which new knowledge assimilation occurs when it is anchored to pre-existing cognitive structures. This process depends on the existence of subsumers (relevant concepts already present in the student's cognitive structure), and the predisposition to learn, in addition to the logical meaning of the material presented (Moreira, 2006, 2011).

From this perspective, it becomes essential to adopt teaching strategies which favor activating prior knowledge and build meaningful relationships between what the student already knows and the new content. Advance organizers, such as introductory texts, videos, or problem-solving questions, fulfill this role by cognitively preparing the student for learning, expanding the possibilities of understanding and retaining the content. When articulated with collaborative practices and experimental activities, these resources contribute to a pedagogical mediation which integrates thinking and doing, strengthening student protagonism (Novak; Gowin, 1984).

It is in this context that the Potentially Meaningful Teaching Unit (PMTU), proposed by Marco Antônio Moreira, is inserted as a didactic methodology consistent with the assumptions of the Theory of Meaningful Learning. A PMTU seeks to intentionally and sequentially organize teaching in favor of establishing substantive and non-arbitrary relationships between new content and students' prior knowledge, configuring itself as an alternative to traditional practices centered on mechanical memorization. By structuring the teaching-learning process in an articulated way, this approach aims to promote deeper, contextualized learning oriented towards developing critical thinking and problem-solving (Moreira, 2006, 2017).

Considering the importance of strategies which dialogue with the cultural universe of students, incorporating elements of pop culture presents itself as a pedagogical possibility aligned with the principles of the PMTU. Movies and anime are widely consumed audiovisual productions by young people which can act as didactic resources capable of mobilizing prior knowledge, stimulating engagement, and contextualizing school content. This type of material promotes interdisciplinary and critical approaches, expanding the potential for meaningful learning. In this sense, the anime *Dr. Stone* (TMS Entertainment/Japan) stands out for exploring concepts related to the scientific method in a narrative which articulates science, society, and problem-solving, addressing themes such as observation, hypothesis formulation, experimentation, and scientific validation.

Based on these theoretical and methodological assumptions, this study investigates how the anime *Dr. Stone* can be used in the context of a Potentially Meaningful Teaching Unit to promote understanding of the scientific method. To this end, the PMTU was structured in four stages: elicitation of prior knowledge; the use of advance organizers; practical activities; and evaluation, described in the methodology, with the aim of articulating theory and practice and fostering meaningful learning of scientific concepts.

## METHOD

This study is characterized as applied qualitative research with exploratory objectives, according to Bogdan and Biklen (1994). The design involved implementing a planned pedagogical intervention in a real school context, accompanied by systematic observation, reflective recording, and analysis of the effects of this intervention on the students' learning process, articulating teaching practice and theoretical reflection.

From the point of view of the objectives, the study sought to investigate how elements of pop culture, specifically the anime *Dr. Stone* (2026), produced by TMS Entertainment, can favor meaningful learning of scientific concepts related to the scientific method. The choice of the anime is based on its narrative, which mobilizes procedures characteristic of scientific

practice (observation, hypothesis formulation, methodology, experimentation, and validation of results) aligning with the knowledge objects of the curricular Biology component in the 3rd year of High School.

Based on the assumptions of the Meaningful Learning Theory, a Potentially Meaningful Teaching Unit (PMTU) was developed and applied, structured according to the steps proposed by Moreira (2011), with the objective of progressively and non-arbitrarily integrating students' prior knowledge with new content. The PMTU was developed as a central pedagogical intervention of the action research, allowing observation of evidence of meaningful learning throughout its application, as well as aspects which could be subject to didactic replanning.

The study was conducted in the first semester of 2024, in a state school in the municipality of Anápolis, Goiás, Brazil, involving 75 students from three classes of the 3rd year of High School, aged between 16 and 18 years. The students' participation occurred by invitation from obtaining an Informed Consent Form (ICF) and the Informed Assent Form (IAF), ensuring the ethical principles of research in a school environment. The researcher acted as the lead teacher during implementation of the PMTU.

The PMTU was structured in four main stages, totaling five class hours. The first stage consisted of surveying students' prior knowledge about the concept of Science through collective and collaborative construction of a word cloud. The students' contributions were recorded on the whiteboard and later noted in the teacher-researcher's logbook, along with observations regarding participation and the concepts expressed.

Next, the inaugural episode of the anime *Dr. Stone* was presented, lasting approximately 24 minutes, made available by the streaming platform Crunchyroll through its official YouTube channel, was used in the second stage as a prior organizer, according to the perspective of Meaningful Learning. After the screening, the students prepared individual essays in which they critically analyzed the social perception of science and scientists, as well as reflected on the representation of science in different audiovisual media. These textual productions constituted one of the data collection instruments of the research.

The third stage consisted of presenting the content related to the scientific method through an interactive lecture linked to an analysis of scenes from the anime which illustrated its different stages. Following this, the students carried out an experimental activity in groups aiming to investigate the influence of the quantity of flax seeds on germination.

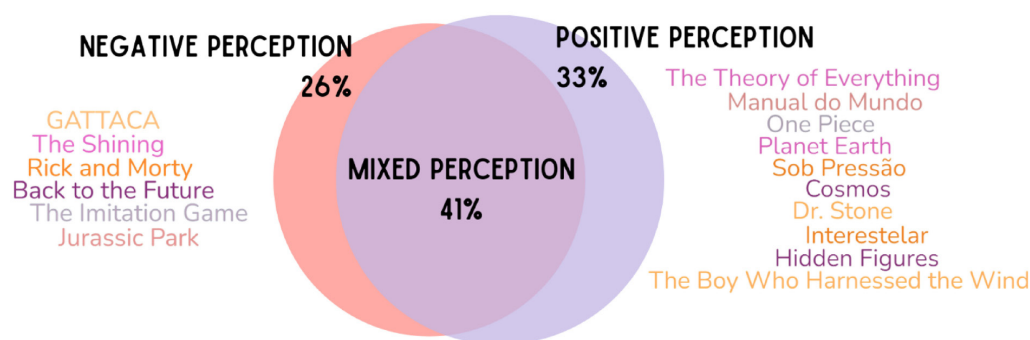
Each group received four containers containing moistened paper towels, in which different quantities of seeds were placed (2, 4, 8, and 16 seeds per container). The containers were kept in a place with natural light, receiving the same amount of water daily. The experiment was conducted over seven days, with daily photographic documentation of the germination process.

At the end of the experimental period, the groups produced videos in which they presented the results obtained and explained the steps of the scientific method used, namely problem formulation, hypothesis formulation, methodology, experimentation, and conclusion. The photographic and audiovisual records produced by the students were integrated into the analysis corpus of this study.

The fourth stage consisted of an individual assessment with the objective of identifying evidence of critical meaningful learning. The assessment included a motivational text and three essay questions related to the anime and the content covered. The answers were analyzed qualitatively and categorized as "presents evidence of critical meaningful learning" or "does not present evidence", considering criteria such as conceptual elaboration, discursive autonomy, and coherence with the assumptions of the scientific method. Merely reproductive or incomplete responses were disregarded as evidence of meaningful learning.

The data were collected through different instruments including: a logbook, textual productions, photographic records, videos, and essay responses, and organized into analytical categories related to the PMTU stages: prior knowledge; use of anime as a prior organizer; interaction with new content; and individual assessment. The qualitative analysis was based on





**Figure 2.** Works of pop culture that reinforce the positive and negative perceptions cited by the students.

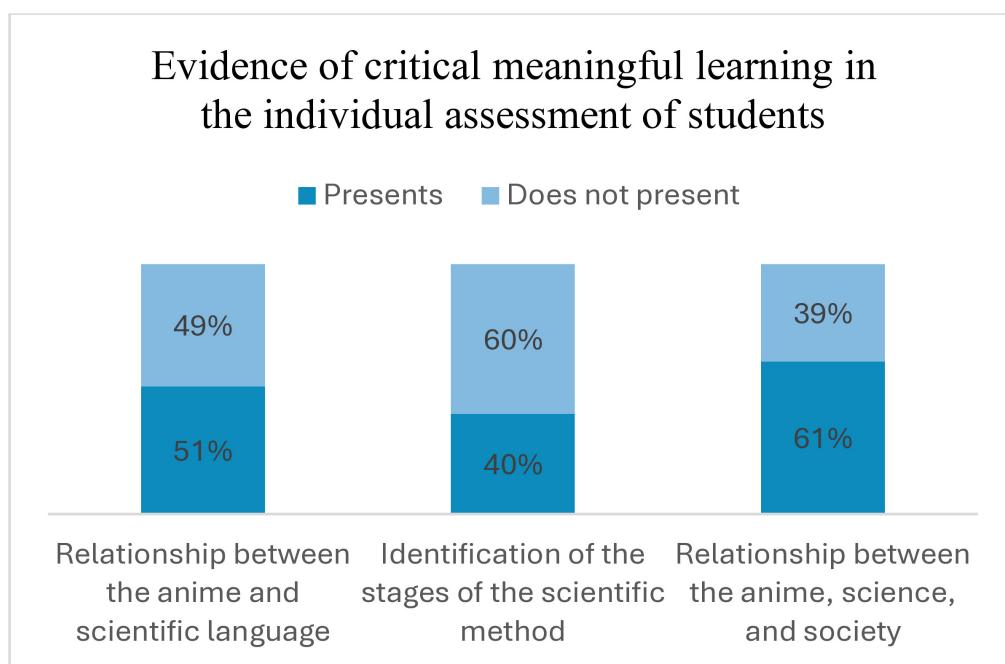
Among the essays classified in the category of negative societal perception of scientists (corresponding to 26% of the total), students associated the figure of the scientist with stereotypes such as social isolation, obsessive behavior, and difficulties in social interaction. These arguments appear articulated in the essays themselves, with the dissemination of fake news and the increase in public insecurity regarding science. In addition, students mentioned extremist religious discourses and the perception of state negligence in supporting scientific development as factors that, according to them, contribute to the social devaluation of science.

On the other hand, 33% of the essays were categorized as a positive societal perception of science. Students highlighted the importance of science for progress in these productions regarding areas such as agriculture, medicine, and technology, portraying the profession of scientist as admirable and associating it with attributes such as intelligence, dedication, curiosity, and commitment to solving problems that affect humanity.

The essays classified in the mixed approach, which corresponded to 41% of the total, simultaneously articulated positive and negative arguments about science and scientists. In these texts, students recognized the relevance of science to development and progress in society, while also pointing out challenges related to the public image of scientists, the circulation of stereotypes, and the difficulty of communication between science and society. Then the activity was performed by all three classes in the third stage of the PMTU concerning the identification of the scientific process present in the anime narrative. The students identified the central problem of the narrative in the analyzed scene (the petrification of humanity), and the hypothesis formulated by the characters that the “reviving fluid” would be able to reverse this process. Experimentation was recognized in the successive attempts to produce the substance using bat guano and ethanol obtained by fermentation until obtaining a result considered effective, which was initially tested on a feather and later on a bird. The conclusion pointed out by the students was the effectiveness of the fluid in reversing petrification.

Still in the third stage, the experimental activity of flaxseed germination was performed by all groups according to the proposed plan. The photographic records showed the seeds’ development throughout the experimental period, indicating variations in germination according to the number of seeds in each container, with a higher germination rate observed in the bags which contained a smaller number of seeds. The students produced videos at the end of the activity, in which they presented the experiment results and described the steps of the scientific method, including problem identification, hypothesis formulation, methodology, experimentation, and conclusion. Variation in the engagement level was observed between the classes, with a greater number of videos submitted by Class 3 and less participation from Class 2.

The data obtained in the last stage of the PMTU, which consisted of individually performing the evaluative activity, are illustrated in Figure 3. The first question, which asked to identify the relationship between anime and scientific language, was answered satisfactorily by 51% of the students, while 49% did not show evidence of significant critical learning. Among the responses classified as evidence of critical meaningful learning, students highlighted how the character Senku uses scientific terms and, at the same time, adapts



**Figure 3.** Evidence of critical meaningful learning in the individual assessment of students through responses crafted in their own words.

his language to make it understandable to other characters and the viewer, as can be seen in the following excerpts:

*Senku uses technical words, such as 'ethanol' and 'nitric acid,' but he explains these terms in a simple way so that Taiju and the viewer understand. In addition, he always makes comparisons with everyday things, such as 'guano juice'.*

Another response presented a similar argument, emphasizing the use of practical examples as an explanation strategy:

*Senku uses practical examples to explain complicated things. For example, when he talks about nitric acid, he not only gives the name, but shows what it does, dissolving the stone. This helps the viewer understand why it is important, even if they don't know chemistry.*

For the second question, which asked to identify the steps of the scientific method used in the episode, 40% of the students presented answers classified as evidence of critical meaningful learning, while 60% did not. The following excerpt stands out among the answers in this category:

*Senku follows the steps of the scientific method by identifying the problem, which is the petrification of humanity, formulating the hypothesis that the fluid could reverse this, testing various mixtures until he finds the right one, and concluding that the fluid works. He also corrects mistakes when something goes wrong, such as in the first attempt to use only guano.*

The third question, which addressed the relationship between science and society, presented the best results, with 61% of the students showing critical meaningful learning, while 39% did not present such evidence. Among the highlighted answers, one student stated:

*The anime shows how science can be used to rebuild society, but it also warns about the danger of it being misused, as in the case of those who caused the petrification. Science is important, but it depends on who uses it and for what purpose.*

Another response offered a complementary perspective, highlighting the collective dimension of scientific practice:

*In the anime, Senku shows that science depends on people. He wants to use science to rebuild society, but he needs manpower to do jobs that require strength, such as collecting guano or carrying stones. This shows that science alone doesn't work; it needs other people to help put knowledge into practice.*

## DISCUSSION

The analysis of students' prior knowledge confirms the centrality of this element in the process of meaningful learning, as proposed by Ausubel (1963), by showing that assimilation of new scientific concepts strongly depends on existing cognitive structures. The recurrence of the term "animals" in the three classes suggests that this concept occupies a privileged position in the students' imagination when they associate science with the school curriculum, while the absence of the term "plants" in one of the classes indicates possible asymmetries in appropriating biological content throughout schooling. These findings reinforce the importance of diagnostic strategies which enable the teacher to not only identify the presence of prior concepts, but also their symbolic and hierarchical organization, guiding pedagogical interventions which are more consistent with the students' cognitive structure.

The associations established by one of the classes between science, "witchcraft", and "fiction" expressively reveal the influence of cultural and historical references in the construction of students' conceptions. By mobilizing these categories, the students resorted to historical and contemporary narratives which situate science either as a persecuted or misunderstood practice, or as an element confused with fictional productions. Far from representing conceptual errors, such associations highlight science as a socially situated construction traversed by values, disputes, and symbolic representations. As Masini and Moreira (2017) argue, unconventional conceptions can constitute powerful starting points for critical discussions about the role of science in different historical and social contexts, broadening its understanding beyond a set of technical procedures.

In this context, the use of the anime Dr. Stone as a prior organizer proved to be particularly relevant, as it enabled students to express their perceptions of science and scientists based on already familiar audiovisual repertoires. The references mobilized in the essays indicate the presence of recurring patterns in the media representation of science. Productions such as Rick and Morty, The Imitation Game, and The Big Bang Theory were associated with stereotypes of eccentric, socially isolated, or emotionally distant scientists, while works such as Interstellar, science outreach programs, and Dr. Stone itself were related to more positive representations, in which science appears as a collective practice aimed at solving social problems.

The coexistence of these readings highlights the complexity of youth perception of science marked by contradictory discourses which combine admiration, distrust, and ethical questioning. Students not only recognize the social relevance of science, but also demonstrate sensitivity to the dilemmas associated with the use of scientific knowledge, such as its misappropriation or its social impacts. These results are consistent with Morales' (2012) findings, highlighting the persistence of media stereotypes in the figure of the scientist, indicating that young people perceive science as an undertaking permeated by ethical, political, and social issues. In this sense, Dr. Stone differs from other productions by not only presenting science as an expression of individual genius, but as a collective undertaking dependent on cooperation, effort, and social responsibility.

With regard to understanding the scientific method, identifying the process stages from the anime's narrative favored contextualizing concepts often treated abstractly in high school. The subsequent inclusion of a didactic experiment on seed germination incorporated into the PMTU (at the request of the students themselves) contributed to deepening this understanding by articulating fictional narrative and mediated experimental practice. This adaptation highlights the importance of pedagogical listening and didactic flexibility, allowing the teacher to act as a mediator of the learning process and enhance the students' predisposition to attribute meaning to the content worked on.

Producing videos to record and present the results of the experiment highlighted both the potential and limitations of the proposal. On the one hand, the records indicated that the

students were able to articulate the problem, hypothesis, methodology, experimentation, and conclusion in a coherent manner; on the other hand, the variation in engagement among the classes points to the need for more targeted pedagogical strategies to ensure effective participation of all groups. This heterogeneity reinforces the importance of a predisposition to learn as a fundamental condition for meaningful learning, as highlighted by Moreira (2011), since meaning is not imposed, but constructed by the student themselves.

The difficulties observed in the individual assessment, especially in the question that required greater conceptual elaboration on the stages of the scientific method, highlight persistent tensions between pedagogical proposals oriented towards conceptual understanding and evaluative practices historically consolidated in the school context. The mechanical reproduction of excerpts from the motivating text by some students suggests the influence of a school culture strongly oriented towards memorization and the search for standardized answers, which can limit autonomous expression and critical reflection. These results indicate that the difficulties observed are not limited to the conceptual domain, but reflect historically consolidated assessment practices in the school context.

As Moreira (2017) points out, meaningful learning requires pedagogical environments in which error is understood as part of the process, favoring construction of one's own answers and attributing meaning to knowledge. In this sense, the results highlight the need to rethink assessment strategies which encourage intellectual authorship, argumentation, and critical reflection in order to align assessment with the theoretical assumptions which guide the proposal of the Potentially Meaningful Teaching Unit.

A discussion of the results generally shows that articulation between pop culture and a Potentially Meaningful Teaching Unit has the potential to promote engagement, contextualization, and critical reflection in science education. At the same time, it reveals that the effectiveness of this articulation depends on continuous adjustments, especially with regard to assessment strategies and the creation of pedagogical environments which value the learning process, intellectual authorship, and understanding science as a human, historical, and socially situated practice.

## CONCLUSION

Applying the Potentially Meaningful Teaching Unit (PMTU) enabled systematically analyzing the contributions and limitations of the articulation between pop culture and science education using the anime *Dr. Stone* as a prior organizer for working with the scientific method in high school. The results indicate that when the use of audiovisual narratives are guided by clear theoretical assumptions and integrated into a structured didactic sequence, they can favor mobilizing prior knowledge and contextualizing scientific concepts which are frequently addressed in an abstract way in school education.

The analysis of the activities developed shows that the anime's narrative contributed to identifying and understanding the stages of the scientific method, especially by associating concepts such as problem, hypothesis, methodology, experimentation, and conclusion with situations recognizable by the students. The inclusion of a didactic experiment incorporated into the PMTU based on the demand from the classes themselves broadened this understanding by enabling a concrete experience of the investigative process, reinforcing the articulation between theory and practice.

The production of videos as a way of recording and presenting experiments proved to be a relevant resource for observing students' conceptual appropriation, as it enabled explaining the steps of the scientific method in their own language. However, the variation in engagement between classes shows that the effectiveness of this type of strategy depends on continuous pedagogical monitoring and conditions which promote equitable participation of groups, reaffirming that meaningful learning is directly related to the student's predisposition to learn, as indicated by Ausubel and systematized by Moreira.

The difficulties observed in the individual assessment, particularly in the question that required greater conceptual elaboration, point to persistent tensions between didactic proposals based on meaningful learning and assessment practices still marked by valuing memorization

and reproducing information. The recurrence of answers based on copying the motivating text suggests the need to rethink assessment instruments so that they promote intellectual authorship, critical reflection, and the student's confidence in constructing their own answers. From a pedagogical point of view, the results reinforce the importance of the teacher as a mediator in the teaching-learning process, responsible for intentionally and contextually articulating scientific content, cultural resources, and teaching strategies. The experience analyzed shows that the use of pop culture in science teaching is not merely a motivational resource, but a possibility for conceptual mediation, provided it is integrated into a structured and theoretically grounded plan.

Finally, this study contributes to the debate on science education by showing that the articulation between cultural narratives and Potentially Meaningful Teaching Units can favor understanding of science as a human, historical, and socially situated practice. At the same time, it highlights that the effectiveness of this articulation depends on continuous adjustments, especially with regard to assessment strategies and the institutional conditions that support pedagogical practices aimed at meaningful learning. Future research could deepen this discussion by investigating the application of similar proposals in other content areas, school contexts, and educational levels, thereby broadening understanding of the limitations and potential of this type of approach.

## ACKNOWLEDGMENTS

The authors thank the Programa de Pós-Graduação em Ensino de Ciências (PPEC) at the Universidade Estadual de Goiás (UEG) for its support in the publication of this article.

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### Authors contribution

BFF: Conceptualization, Methodology, Data curation, Investigation, Formal analysis, Validation, Data visualization, Writing. SXS: Project administration, Conceptualization, Methodology, Data curation, Formal analysis, Validation, Data visualization, Review.

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