USE OF PEDAGOGICAL PRACTICES FOR THE TEACHING OF BIOTECHNOLOGY IN HIGH SCHOOL

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ABSTRACT

The National Common Curriculum Base (BNCC) highlights the importance of technological knowledge, including Biotechnology. This study, developed as part of the activities of the Institutional Program of Scholarships for Initiation to Teaching (PIBID) Degree in Chemistry IFF Campus Itaperuna, aimed to develop innovative educational practices for the teaching of Biotechnology in high school. To this end, active methodologies were used, such as interactive presentations such as mind maps and slides, educational games, practical experiments and technical visits. The presentations were given to students in the 1st, 2nd and 3rd year of high school and to students in the 1st and 2nd year of the normal course for teachers. During the applied activities, fixation exercises were given, and the results showed that initially the students had little knowledge about Biotechnology, but developed significant interest during the activities. The students identified in several areas of their daily lives that Biotechnology was present, and showed high engagement, especially in practical activities and games. And, through specific questionnaires applied at the end of the practices, quantitative data were obtained that revealed that 87.3% of the students of the Normal Course and 92.7% of the High School students answered 70% or more of the questions about Biotechnology, with general averages of 8.7 and 9.1 correct answers (in 10 questions). The qualitative evaluation in relation to the presentations and the chosen subject was positive, with the students highlighting terms such as "interesting" and "important" to describe the activities. With this, it can be concluded that the pedagogical resources used were efficient for the teaching and dissemination of Biotechnology.

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INTRODUCTION

Biotechnology is an ancestral science, used by human beings for a long time, since they made the first bread, produced the first glass of wine and selected the best grains for the replanting of the new crop. It evolved with milestones such as the discovery of penicillin by Alexander Fleming and the structure of DNA by James Watson and Francis Crick. Living organisms are used as "factories" to produce medicines, food, biofuels, and chemicals, as well as contribute to advanced diagnostics, disease treatments, increased agricultural productivity, and sustainable environmental solutions (Relly, 2024; Rodrigues et al., 2015).

In environmental preservation, Biotechnology is very present, contributing to advances in green chemistry, which aims to develop processes and chemicals that reduce or eliminate the use and generation of substances that are harmful to the environment and human health. For example, in the remediation of contaminated waters, biodegradation of pollutants and biofuels; development of sustainable industrial products, such as bioplastics, among others (Amorim, 2019). The development of biodegradable bioplastics contributes to reducing the amount of waste. Since bioplastic is a type of plastic material produced from renewable sources (such as casein, which is milk protein). This is an example of the multiple applications of Biotechnology in green chemistry (Carvalho; Licco, 2017).

According to Fonseca, Bianchi, Stallivieri (2010) Biotechnology is an important area of innovation and development in multiple sectors of the Brazilian economy, contributing to the country's development. However, the number of companies participating in modern Biotechnology is still small, the authors found that, between 2008 and 2009, 92% of Brazilian companies developed biotechnological products and 85% worked with processes in the biotechnology area. However, only 54% of these companies were able to bring their products to market, making explicit a significant gap between research and commercialization. This analysis is complemented by Florêncio et al. (2020) whose study shows that, in the period from 2000 to 2016, biotechnology patents represented only 2% of the total granted in the country. The study reveals that, of the 1,592 biotechnology patents granted in this period, only 161 (about 10%) belonged to holders residing in Brazil. Making it necessary for there to be more and more collaboration between universities and Brazilian companies for the development of new biotechnological products and processes. This advance can strengthen Brazil's competitiveness in the global market and stimulate job creation and investments.

In practice, Biotechnology mixes several areas of knowledge, such as: chemistry, biology, biochemistry, microbiology, philosophy, among other areas. Biotechnology studies are applied in the scientific, agronomic, medical, industrial, energy, chemical and environmental fields (Lima; Santos, 2022).

Currently, the subject of Biotechnology is being addressed in several entrance exams and even in ENEM, in addition to the fact that it is a multidisciplinary area that involves the application of knowledge in biology, chemistry, physics, philosophy, engineering, among others, to create innovative solutions in various areas, such as health, agriculture, environment and industry (Oliveira; Benevides, 2024).

Numerous challenges for education have presented themselves in the twenty-first century, especially in technological advances and transformations in the labor market. These changes have stimulated the search for new approaches in pedagogical training. In this context, the implementation of the BNCC (National Common Curricular Base) (Pelizzari et al., 2022) stands out. In the BNCC itineraries, three of its general competencies involve technological knowledge, namely: i) languages and their technologies; ii) mathematics and its technologies; and iii) natural sciences and their technologies. In addition, these training itineraries may have the possibility of constituting integrated training itineraries, that is, those that combine more than one area. And, through Biotechnology, which is a multidisciplinary science, students will be able to access the skills described by the curriculum. As Biotechnology is not widely addressed in the discipline of Chemistry in High School, this work will allow us to observe its contributions over the years and its presence in the daily lives of students (Brasil, 2018).

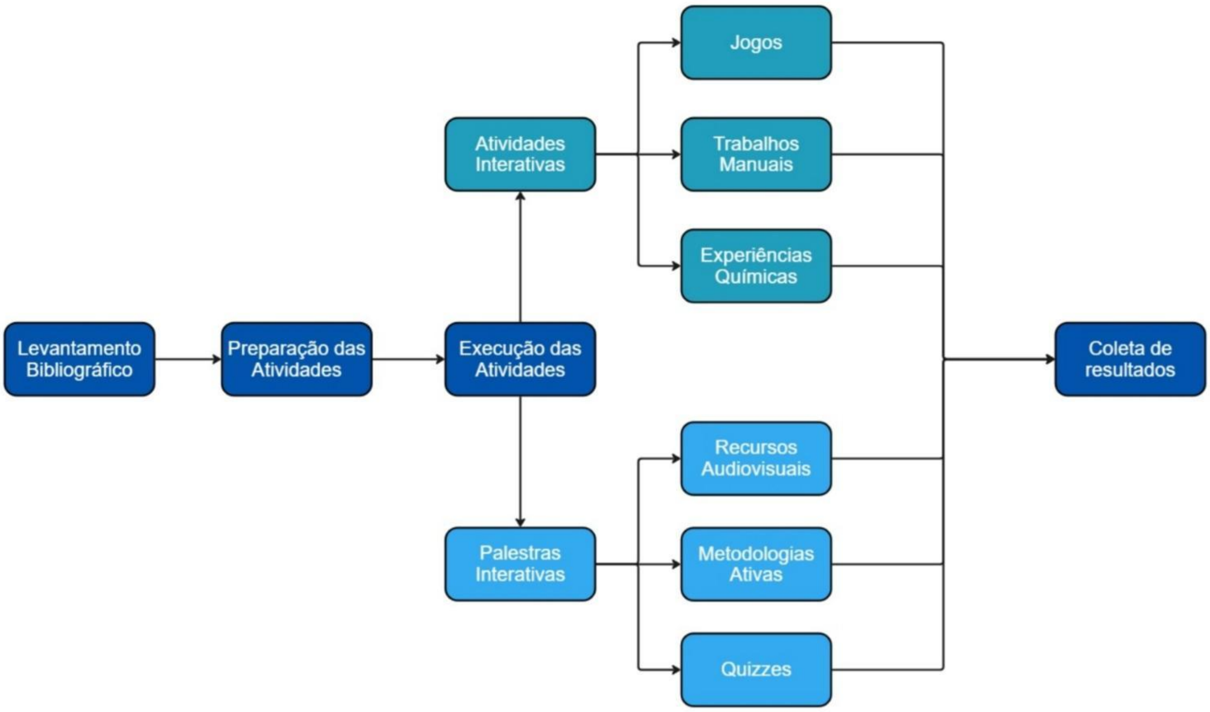
The approach to Biotechnology in High School requires pedagogical strategies that promote meaningful learning and the development of critical thinking in students. For this, the Luckesian perspective is adopted, which understands evaluation as a continuous and formative process, aiming at the construction of knowledge in a reflective and participatory way. This approach allows the activities proposed in Biotechnology to be planned in order to promote critical reflection and the active participation of students, aiming at overcoming errors as learning opportunities and the development of essential skills for the understanding of scientific concepts (Luckesi, 2008).

This work aimed to (1) apply and develop current pedagogical practices in the teaching of Biotechnology for high school students and the normal course of teachers; (2) to evaluate the impact of these practices on the improvement of students' critical-scientific thinking; and (3) disseminate the importance of Biotechnology for science, public health and the environment, among other areas.

METHODOLOGY

This work was carried out at the Ciep 263 Doutor Jair de Siqueira Bittencourt school in the city of Itaperuna/RJ, with students from the 1st, 2nd and 3rd year of high school and students from the 1st and 2nd year of the Normal Teacher Course. He was part of the Institutional Teaching Initiation Scholarship Program (PIBID) from 2023 to 2024. The project was organized in a sequence of four main stages, as illustrated in Figure 1 below.

Figure 1. Flowchart of the methodology used.



Source: Prepared by the authors themselves, 2025.

The work began with the bibliographic survey, this first stage was separated for a thorough research on the subject of Biotechnology, where the academic material that would be used as a basis for all the following processes was separated. Books, articles, reports and technological resources were selected to support the activities that would be carried out. All the subjects chosen within this area were in accordance with the BNCC, to have a better framework within the current context of the school.

After this stage, the Preparation of Activities was carried out, first of all, all the theoretical material was prepared to establish a conceptual basis with the students, an essential condition for it to be possible to move on to other types of activities. The resources used were mind maps developed on the Mindmeister digital platform[5], used as

[5] Mindmeister is a digital platform for creating interactive mind maps, which allows you to organize and visualize concepts in a dynamic and hierarchical way through visual structures, logical connections, and multimedia integration (images, links, and texts). Available at: https://www.mindmeister.com/pt.

an introductory tool for the main themes of Biotechnology; interactive slides were also formulated for the presentation of the contents. At the end of each class, the Wordwall website was used[6] to apply online educational games with the students. These games, based on the Biotechnology themes addressed, allowed interaction both together and individually via mobile devices.

In the subsequent stage, the pedagogical resources that would be used for the programmed activities were organized, such as games, handicrafts, laboratory practices in the classroom and laboratory, technical tours and films. Some materials used were: datashow, speaker, stationery items, laboratory glassware, chemical products, food ingredients (for specific experiments), transportation (properly planned and authorized for educational visits), among other items.

The execution of the activities was structured in two main phases, as illustrated in Figure 1 above.

INTERACTIVE LECTURES

a) All lectures were conducted with the support of audiovisual resources, including mind maps, slide presentation and screening of the film "Radioactive" (based on the life story of scientist Marie Curie);

b) In each class, the interaction of students in class was sought, for this some active methodologies were used, such as problem-based learning (PBL), with case studies related to the applicability of Biotechnology in everyday life (e.g., vaccines, transgenic foods); Digital educational games (such as Wordwall quizzes and themed word searches). Before each activity, a diagnostic evaluation of the students' previous knowledge was carried out through quick questions. This survey allowed us to make use of this previous knowledge and contextualize the contents with the students' experiences, transforming their experiences (such as the management of plants at home or the consumption of biotechnological products) into concrete pedagogical elements;

c) As the students transmitted their experiences, they were incorporated into the planning of the activities, such as the reports that the students had doubts about their veracity were saved to be used in future works. Many doubts arose in the health

[6] Wordwall is an online platform that allows the creation of interactive educational games, such as quizzes, word searches, and matching activities, making it easier for students to engage in the learning process. Available at: https://wordwall.net/pt.

area, and with that, a specific lecture was developed on biotechnology applied to vaccines, meeting the suggested demands;

d) At the end of each of the lectures, educational games were applied exercising the critical-scientific knowledge of the students and, after all the activity was done, online quizzes via Google forms were applied, to have an immediate evaluation of the students' learning. The continuous analysis of the results of these quizzes served as a tool for pedagogical monitoring, thus assuming a formative character of the evaluation of student learning.

2.2 INTERACTIVE ACTIVITIES

a) Educational games such as the periodic table game, the truth game or fake games were executed. These games served to stimulate group work and critical-scientific thinking of the students;

b) The handicrafts done were focused on the subjects that were being applied in the school curriculum, the activities were the making of a mural on organic chemistry and the elaboration of fanzines on chemical bonds;

c) The chemical experiments carried out were the demonstration of an acid-base indicator with red cabbage as a pH indicator (in the classroom) and the production of bioplastic from milk casein (in the laboratory of the IFFluminense *campus* Itaperuna);

d) A technical visit was made by the students of the CIEP 263 school to the IFFluminense *campus* Itaperuna to participate in the 10th Academic Week and they visited the thematic rooms, including the thematic room of PIBID.

Finally, at the end of the activities, the results obtained were systematized and analyzed, as shown in Figures 11, 12 and 13 and Table 1.

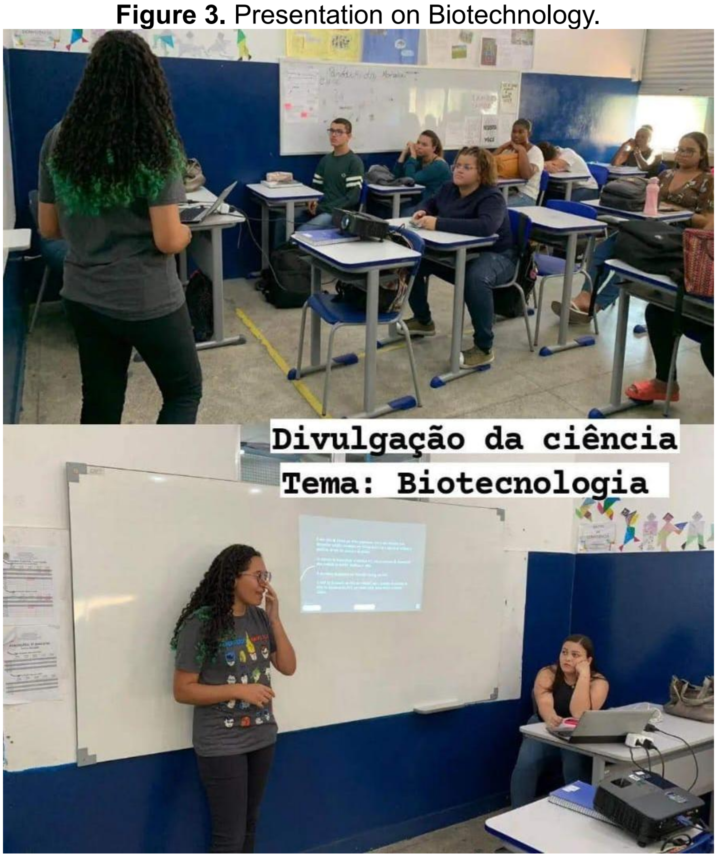
RESULTS AND DISCUSSIONS

The results were evaluated by means of photographic records (Figures 2 to 10), questionnaires (Figures 11, 12 and 13) and qualitative evaluation by the students in relation to all the work done (Table 1).

Figure 2. Presentation on Biotechnology.

Source: Prepared by the authors themselves, 2025.

Figure 3. Presentation on Biotechnology.



Source: Prepared by the authors themselves, 2025.

As illustrated in Figures 2 and 3, the didactic activities were developed through the use of audiovisual resources such as mind maps and slide presentations (projected via datashow). These pedagogical tools served to provide an introductory basis for the study of Biotechnology, addressing its theoretical foundations, historical evolution, current applications and main areas of activity (health, agriculture, livestock, environment, economy). All the knowledge built in these theoretical sessions was later applied in subsequent practical activities.

As a strategy to consolidate learning, at the end of each lecture, online educational games were held, such as word search and hangman, which allowed students to play together or on their mobile devices individually. This playful approach demonstrated effectiveness in student engagement and in the fixation of the concepts worked.

It is interesting to highlight two activities, first the thematic lecture on Biotechnology applied to vaccine development, which addressed the historical context, the relevance of vaccines in the post-pandemic scenario (emphasizing the lessons learned from COVID-19). And, as a complementary practical activity, the students carried out a critical analysis of their vaccination cards (previously requested), allowing the identification and understanding of the different types of vaccines.

In the second instance, the screening of "Radioactive", a biographical film of Marie Curie, was used as a panorama for the approach of radioactivity applications, the journey of women in science, the discrimination faced by Curie in academia related to her gender and nationality, the discovery of radioactive chemical elements and the dangers of radiation. The feature film allowed the students to visualize and debate the methodology and the series of events that triggered the classification of the Polonium and Radium elements.

These types of methodological approaches proved to be effective in contextualizing the theoretical contents and strengthening the connection between academic knowledge and the personal experiences of the students.

Figure 4. Periodic table set.

Source: Prepared by the authors themselves, 2025.

As evidenced in Figure 4, the activity "Periodic Table Game" was carried out, which consisted of using a large-scale periodic table (Figure 4) as a physical board, projecting the interdisciplinary questions via datashow and with the students divided into competitive teams. The content covered was multidisciplinary encompassing concepts of chemistry, physics, biology and general scientific knowledge, emphasizing the topics of Biotechnology previously worked on in the lectures.

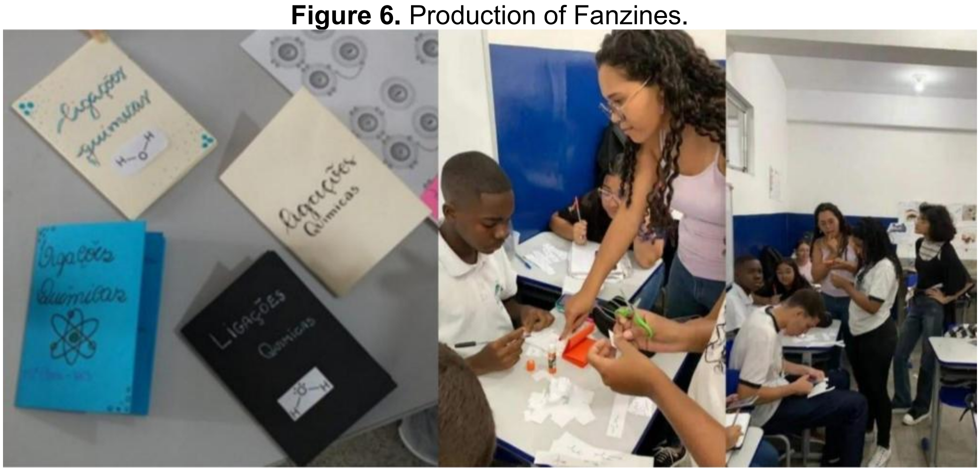
A high degree of interaction between the students was noted, where they demonstrated their previous and acquired knowledge about the subjects, further developed their critical-scientific thinking and strengthened teamwork. This game demonstrated the effectiveness in consolidating the concepts previously worked on and, therefore, being a formative assessment tool.

Figure 5. Students with the organic chemistry mural.

Source: Prepared by the authors themselves, 2025.

As shown in Figure 5, the activity "Mural of Organic Chemistry" was developed, in which the students elaborated the graphic representation of the main organic functions, identifying and naming them. The activity was carried out collaboratively, the students themselves set up the mural in the classroom. This activity facilitated the visual learning of abstract concepts of organic chemistry, providing a playful approach to complex content, helping in the mnemonic retention of the concepts. It also served as a diagnostic tool for the conceptual domain of students in the 3rd year of high school.

Figure 6. Production of Fanzines.



Source: Prepared by the authors themselves, 2025.

The fanzines applied to the teaching of chemistry, illustrated in Figure 6, addressed the respective subjects seen in the period by the second (organic functions) and first (chemical bonds) classes of high school. In these workshops, students were taught how to produce handmade magazines (fanzines), which they filled with previously provided materials, which they had to correctly organize in the magazine. The students were free to decorate the magazine, stimulating their autonomy and also encouraging spatial reasoning, since it was necessary to reconcile their aesthetic visions with the information that should be inserted. In the end, the products were summaries of the materials produced by the students, who remained in their possession for future help in their studies.

Figure 7. Red cabbage experiment as a natural pH indicator in the classroom.

Source: Prepared by the authors themselves, 2025.

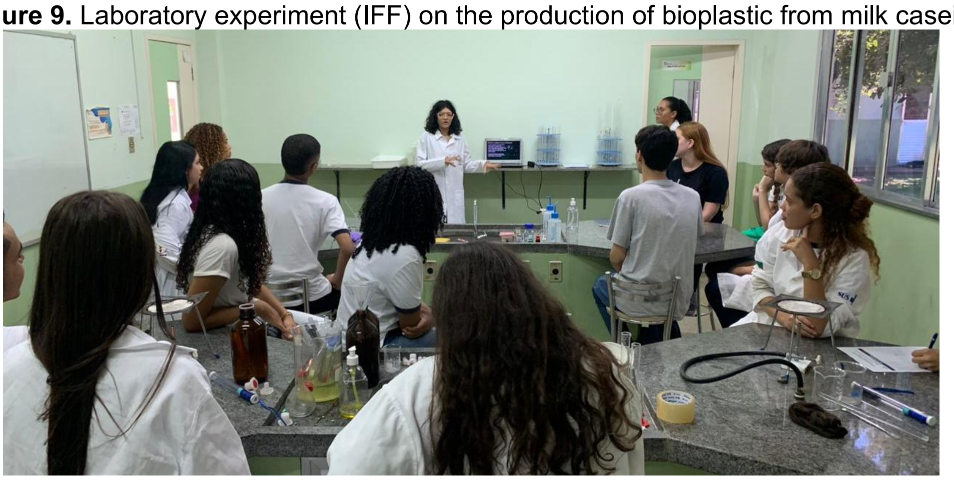
Figure 7 shows the didactic experiment using red cabbage as a natural pH indicator, with the following aspects: the red cabbage solution was previously prepared and then the substances for analysis were selected (such as household cleaning products, foods such as lemon juice, soda and water from the school drinking fountain). The students had to formulate hypotheses about the acid-base character of each substance, then tested it with the natural indicator, in this step, they made a correlation between the colors obtained and the pH scale (a table with this information was provided). This activity was directly related to the chemistry curriculum content and demonstrated basic concepts of the content covered. The involvement of the students was good, the previous conceptions of the students were compared with the experimental evidence and the theoretical concepts of acid-base were contextualized with real situations.

Figure 8. Visit of CIEP 263 students to the thematic room of the IFF academic week.

Source: Prepared by the authors themselves, 2025.

As documented in Figure 8, a technical visit was made to the 10th academic week of the IFFluminense Itaperuna Campus. The students visited the thematic room of PIBID (Initiation to Teaching and the Use of Technologies in Critical Perspective), where students and the entire community in the region were able to see an interactive exhibition of the active methodologies implemented in each center of action. The room was composed of practical demonstrations of pedagogical activities, exhibition of didactic material, educational games, visual and playful elements.

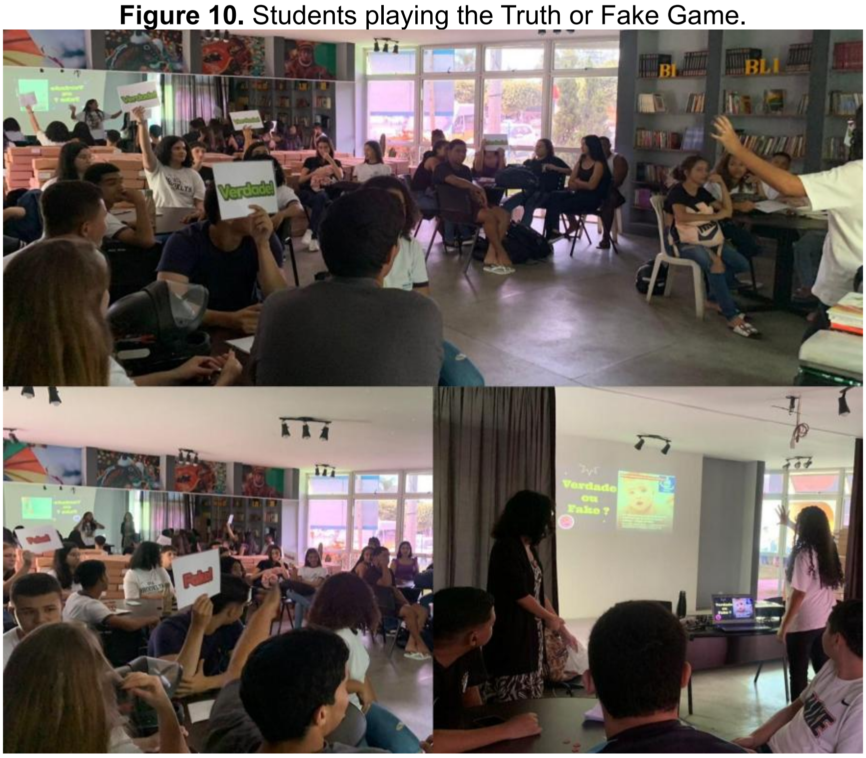
Figure 9. Laboratory experiment (IFF) on the production of bioplastic from milk casein.



Source: Prepared by the authors themselves, 2025.

Another experiment carried out was the workshop for the production of bioplastic from milk casein, in the chemistry laboratory of the IFF, as shown in Figure 9. This activity aimed to use bioplastics as instruments to approach the topic of polymers in the teaching of chemistry, for this it was composed of two stages, one corresponding to the conceptual introduction and the next dealing with practical experimentation, in a previously prepared laboratory. For the theoretical initiation, expository slides were presented, discussing the conceptualization of the definition and characteristics of polymers, then, an activity based on the conduction made through the slides, the students produced the galalite, with the freedom to mold and customize the appearance of the parts before they are soaked in formaldehyde for the plastic hardening process. The entire process of the experiment was carried out in the chemistry laboratory of the IFFluminense *Itaperuna Campus* and, when ready, the pieces were returned to the students.

Figure 10. Students playing the Truth or Fake Game.



Source: Prepared by the authors themselves, 2025.

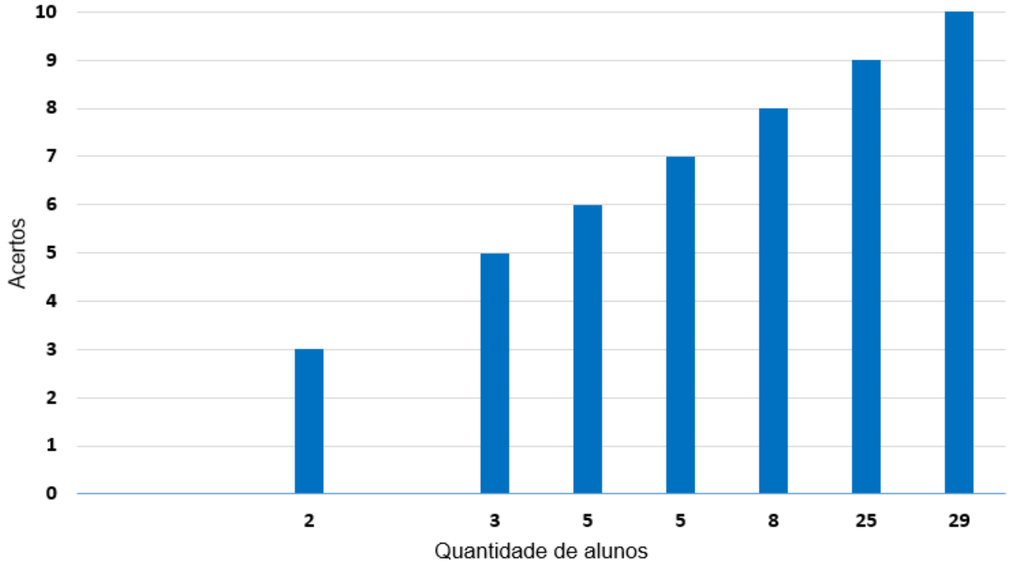
Figure 10 shows the implementation of the didactic game "Truth or Fake", structured as follows: scientific news (true and false) was selected from various sources (including materials brought by the students themselves) and, at the time of the game, a previous training was carried out on the techniques for identifying disinformation, it was also a moment in which there was the possibility for students to put into practice the knowledge acquired from all the lectures of Biotechnology. The students then made a collective analysis of the reports, debated the veracity of the information and, finally, had a scientific validation of their conclusions. Through this game, a significant improvement in the ability to critically analyze information was noted, the concepts of Biotechnology learned by the students were also applied in practice, being able to develop their scientific argumentation skills and a high level of engagement in the interaction of the participants was obtained.

The data presented below in Figures 11 and 12 demonstrate the results of seven different questionnaires applied to students in High School and the Normal Teacher Course. These evaluation instruments were applied immediately after each thematic lecture on Biotechnology and also after the practical activity of bioplastic production, totaling: Normal Teachers' Course: 77 students responded; High School: 128 students responded; Bioplastic activity from milk casein: All 19 students present responded.

The questionnaires, prepared in Google Forms, were composed of multiple-choice questions (with 3 to 4 alternatives each, only one of which was correct), developed based on the specific content addressed in each presentation. The support material used to formulate the questions was the same that supported the presentations, ensuring coherence between the content taught and the evaluation.

The successful application in the classroom, right after each activity, with the students responding immediately, allowed the evaluation of the understanding of the concepts at the time they were disseminated, providing significant data regarding the effectiveness of the pedagogical practices carried out.

Figure 11. Analysis of the Biotechnology questionnaire of high school students - Normal Teacher Training Course

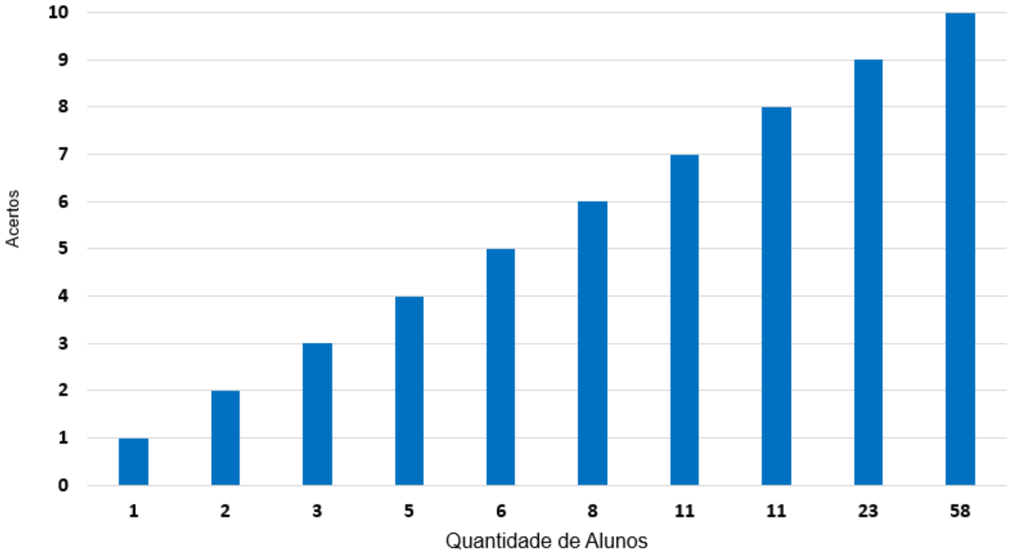


Source: Prepared by the authors themselves, 2025.

Examining Figure 11, 29 students (37.7%) achieved the maximum score (10/10), 25 students (32.5%) got 9 of the 10 questions right, and only 2 students performed below the average number of correct answers. Obtaining an overall average of correct answers of 8.7 questions, which shows that 70.2% of the students got 9 or 10 questions right. The concentration of correct answers in the maximum scores corroborates the effectiveness of active methodologies in the teaching of Biotechnology (used in the high school classes of the Normal Teachers' Course) in the fixation of concepts and in the analysis of scientific information. It is important to highlight that as these results are due to the students of the Normal Teacher Course, it is a great experience for students, as they can replicate these strategies in their future classes, expanding the impact of the study.

The small portion of students with performance below this average of 8.7 questions may be associated with individual difficulties that are not met, which can be met by personalized monitoring and an expansion of resources to diversify teaching tools.

Figure 12. Analysis of the Biotechnology questionnaire of high school students.

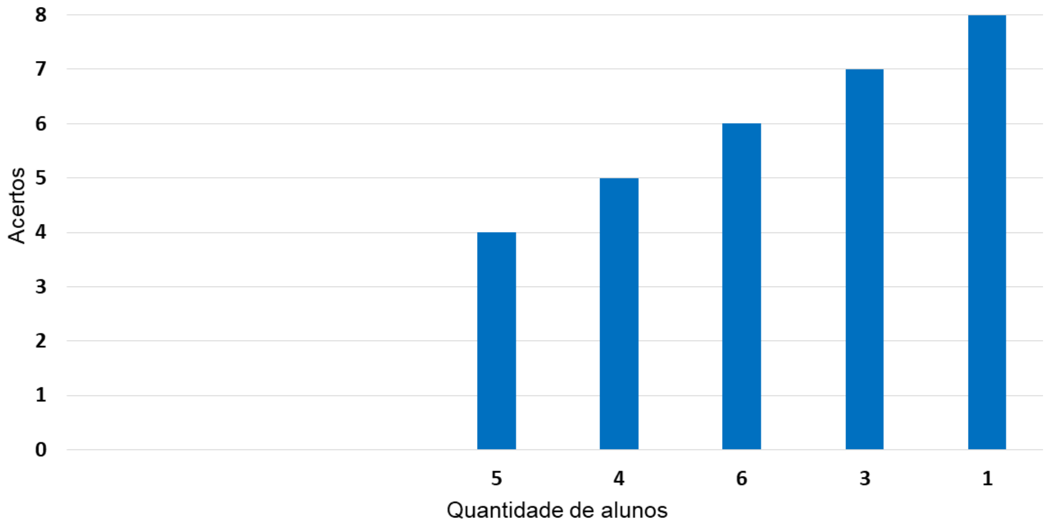


Source: Prepared by the authors themselves, 2025.

Figure 12 shows the distribution of correct answers among high school students, 58 students (45.3%) got all the questions right, 23 students (18.0%) got 9 of the 10 questions right, only 3 students (2.4%) had a performance below 30% of the correct answers. Thus, obtaining an overall average of correct answers of 9.1 questions. The rate of 63.3% of students having answered 9 or 10 questions correctly reinforces the effectiveness of the approach used for the vast majority of students and confirms the accessibility of the method for different student profiles.

However, the data also reveal an opportunity for improvement for the groups with lower performance, such as 25 students who got between 1 and 6 questions right. Large classes (such as those worked) can limit the ability to identify and correct specific questions during activities. Among the possible causes of this low performance are: gaps in previous concepts, students with a more theoretical or introspective profile, and also the lack of individualized follow-up. To mitigate problems like this, it is suggested to diversify methodologies, such as including case studies, explanatory videos, or illustrated summaries so that students can study at home.

Figure 13. Analysis of the answers to the questionnaire of the Bioplastic production workshop.



Source: Prepared by the authors themselves, 2025.

When analyzing Figure 13, out of a total of 19 students, it is observed that one student (5.3%) achieved the maximum score, 3 (15.8%) got 7 questions right, 6 (31.6%) got 6 questions right, and all students had a performance greater than or equal to 50% in the questionnaire. Thus, the efficiency of such a methodology is established, requiring adjustments to maximize its results.

It is observable how a large portion of the students obtained six correct answers, in this situation it was possible to identify two specific questions that presented errors in common. In one, there was a confusion between the terms "rubber" and "elastic" by the term "elastomer", which should be mentioned in the question. In the other, most of the students were not able to link the characteristics described to phenol-formaldehyde, the material used in the experiment to solidify casein. The students presented greater difficulty in questions that reflected the experience done in the laboratory, demonstrating occasional difficulty in associating the theoretical basis with practice, this can be justified by the fact that the laboratory was a new environment for the class and by the theoretical basis having been introduced prior to the experimentation, but which ideally was designed to be carried out one week before the practice so that the students could assimilate the content, which was not possible due to calendar issues of both IFF Itaperuna and CIEP 263.

Below, Table 1 details the level of student engagement in the activities, listing the words most used by students to describe them:

Table 1. List of the words that the students used to evaluate the activities carried out.

Words	Number of students who used this word
Good/Good	57
Interesting	32
Important	12
Great	22
Teaching	3

No opinion	10

Source: Prepared by the authors themselves, 2025.

The terms "Good" and "Interesting" predominated, indicating a positive acceptance of the methodologies applied. This engagement of the students is of great importance because it suggests that the participants valued the practical experience that was a little different from the traditional approach. This feedback from students reinforces the need for innovative methods in the teaching of Biotechnology.

It is important to highlight that it was not possible to use more technological resources due to the school's limitations, it is expected that improvements in infrastructure and increased resources will be carried out so that it is possible to use other resources, such as *online games* that today greatly encourage student interaction, due to their interest in the area. The lack of a reserved space such as a chemistry laboratory also limited the experiments that would be carried out, as can be seen in the activity of producing bioplastic from milk casein that had to be carried out at the IFF, due to the lack of structure at the CIEP 263 school.

CONCLUSION

The results of this study demonstrate that the active methodologies applied were effective for the teaching of Biotechnology, achieving the three proposed objectives, as the pedagogical practices such as combinations of interactive lectures, educational games and practical activities proved to be efficient, as evidenced by the high rates of correct answers. The students' performance in the activities, especially in the "Truth or Fake" game, and in the questionnaires, demonstrate the development of critical-scientific thinking. In addition to the mastery of the basic concepts of Biotechnology (present in the most correct questions) they indicate success in scientific popularization.

The success of this experience is largely due to the PIBID program, which is indispensable in the training of students in licentiate since it brings them closer to the school reality, allowing them not only to develop the necessary skills for the exception of their future profession, but also to obtain significant experiences for their performance, being a fundamental initial contact between the undergraduates and the classroom. Another major component for this outcome was the fundamental guidance of the supervising teacher Vivian Leite, whose pedagogical mediation was essential, since the Luckesian approach to these activities was successful thanks to the formative vision that the teacher adopts in relation to the evaluation of learning, elaborating the distribution of scores based on the learning of the teachers and allowing the next activities to be sustained in their reality. The continuous exchange of experiences between the Pibidians and the teacher in practice generated a unique synergy, where the dialogue between initial training and classroom experience resulted in direct benefits for the students, both in the mastery of biotechnological concepts and in the development of scientific skills. This collaboration exemplifies how partnerships between training institutions and schools can revolutionize science education, in a truly accessible way and analogous to the realities of local communities.

This work contributed with a replicable model for the teaching of science in basic education, highlighting the importance of approaches that combine theory and practice, and, as future directions, the study suggests that this model be adapted to local realities when applied. The correlation between the initial problem (difficulty in teaching Biotechnology) and the results obtained indicates that interdisciplinary and participatory approaches, when well planned, can transform the teaching of complex topics into meaningful experiences. It is recommended that this work be expanded to other areas of the natural sciences, with special attention to the continuing education of teachers and the strengthening of partnerships between schools and higher education institutions. The study shows that Biotechnology, when worked in an interdisciplinary and participatory way, can arouse the interest of students and prepare them for contemporary technological challenges.

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