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STEAM Approach Focusing on Natural Sciences and Geometry in the Proliferation of Pigeons

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Abstract

This paper aims to analyze the STEAM approach in teaching Natural Sciences and Geometry in a Brazilian school. It is an excerpt from a study conducted with a view to disseminating investigative and creative pedagogical practices in K-12 Education. The teaching experience based on the STEAM approach, which is the focus of this article, explored the problem of the proliferation of pigeons in the surroundings of the school community identified by the students themselves. The scientific methodology applied in this study was Action Research, of a qualitative and exploratory nature. The data sources were the logbook, questionnaires, multimedia recordings and the productions developed throughout the investigative and creative practice. The research was developed in a peripheral school in Natal/RN, in northeast Brazil, in a second-year high school class with 32 students, in which the study of Geometry was planned for the entire school year. The results showed that the integration of STEAM areas, such as pedagogical practices in combating the proliferation of pigeons involving Mathematics, focusing on Geometry, and Natural Sciences, mobilized Hoffer's (1981) skills and critical thinking, collaboration, communication and creativity, as well as providing opportunities for student protagonism. It is concluded that the STEAM approach placed the student at the center of the learning process and provided opportunities for the mobilization of cognitive and socio-emotional skills in an application relevant to the school community chosen by the students.

INTRODUCTION

Research shows alarming data on the low learning performance of K-12 Education Brazilian students in Mathematics and Science. For example, the Program for International Student Assessment (PISA) showed that 73% and 55% of students did not achieve the minimum skills necessary for their citizenship development in Mathematics and Science, respectively (Organization for Economic Cooperation and Development [OECD], 2023). Thus, these figures indicate that students in the final grades of Elementary School have not achieved the basic academic competencies and skills aligned with the Common National Curriculum Base (BNCC[1]) for this stage and expected by the Brazilian Ministry of Education (MEC), with this deficit being reflected in the High School stage (Brasil, 2018).

Mathematics and fields like Science have long been recognized for their utilitarian nature in everyday situations. Furthermore, Geometry has always played an important role in connecting the nature of mathematical thought, from the concrete to the abstract. However, there is still a large gap to be filled by the need for its humanistic, social, and cultural natures in school education, as "It is not possible to build knowledge dissociating the rational from the mythical, the sensory, the intuitive and the emotional dimensions" (D'Ambrósio, 2019, p. 166).

The STEAM approach, an acronym for Science, Technology, Engineering, Arts, and Mathematics, proposes uniting these areas in favor of investigative and creative practices that develop students' active and creative cognitive and socio-emotional abilities, drawing on different areas of knowledge in an inter- and transdisciplinary manner to solve problems (Maia *et al*, 2024). According to Bacich & Holanda (2020), STEAM projects seek to address real and authentic problems for students, enabling them to think, investigate, conjecture, argue, prototype, and design possible solutions. They involve knowledge and skills from different school disciplines to mobilize their different human dimensions, allowing them to be applied at various levels of education.

Some studies demonstrate a lack of dissemination of STEAM-based pedagogical practices in Brazil. Maia, Carvalho & Appelt (2021) found only eight Brazilian studies, relevant for further analysis, in the Google Scholar database, published between 2015 and 2020. The results revealed five studies from the South of the country, two from the Southeast, and one from the Central-West. No studies were found in the North and Northeast, the country's poorest regions, highlighting educational inequalities. Four studies were conducted in High School, three in the final grades of Elementary School, and one in the Early grades of Elementary School.

[1] Although this document is referred to in the text by its English translation, Common National Curriculum Base, we have chosen to retain the original Portuguese acronym, *BNCC (Base Nacional Comum Curricular)*, as it is the widely recognized and standard designation within Brazil.

Furthermore, most studies were applied to areas within the Natural Sciences, but some involved collaboration with Mathematics or Computer Science teachers, as well as Engineering students. In terms of pedagogic methodologies, Project-Based Learning (PBL) and Maker Culture were the main allies in STEAM practices. Furthermore, their use encouraged the exploration of different non-traditional school spaces, such as Computer Science and Science labs. Finally, student protagonism, as well as soft and hard skills, were mobilized in STEAM practices (Maia, Carvalho & Appelt, 2021).

Other review studies such as those carried out by Lourenço (2024) and Soares and Maia (2023) reinforce the scarcity of works contemplating the STEAM approach in the context of High School in Brazil, that specifically associated with the Teaching of Geometry, in which only one work developed in Brazil was found, and this one with the Teaching of Chemistry, of which none was found, considering the time frame used in each study.

Thus, this excerpt from Lourenço's thesis (2024) aims to analyze the STEAM approach in teaching Natural Sciences and Geometry in High School.

STEAM APPROACH IN TEACHING NATURAL SCIENCES AND GEOMETRY

The STEAM approach emerged in the 1990s in the United States by the National Science Foundation (NSF) under the term SMET, an acronym for Science, Mathematics, Engineering, and Technology. The goal was to train students for the so-called "hard" or "exact" fields to meet the demands of the job market. Over time, some reforms were made to its design, addressing the importance of including "soft" fields, or areas of the Humanities and Social Sciences, for students' full exercise of citizenship, changing the order of the acronym to STEM. Subsequently, the "A" for Arts was integrated into STEM practices, adding greater sensitivity to projects and creative freedom, enriching the mobilization and construction of knowledge. This process became known as STEAM (Cavalcante, Barbosa & Silva, 2021; Moreira, 2021).

The STEAM approach is "an approach to pedagogical work that fosters the development of creative and active learning, enabling students to make decisions and evaluate results through interdisciplinary projects that seek to solve real-world problems" (Maia, Carvalho & Appelt, 2021, p. 70). STEAM practices foster student empowerment, the exploration of diverse skills, the integration of different areas of knowledge into projects, the promotion of creativity, peer collaboration, and access to non-traditional learning spaces.

The conception of STEAM Education fostered in this paper is like an approach, that:

> "(...) as more than just working with the set of disciplines and/or areas that compose it, or even as a methodology or a pedagogical trend. It is a proposal

> for educational innovation that brings together the fields present in the acronym, with their knowledge and procedures, to carry out investigative and creative practices in the classroom. It is about addressing problems with the scientific method and rigor characteristic of the Sciences; proposing Technologies to represent (whether in physical, virtual/digital, or procedural form) and to solve problems; promoting the ingenuity and prototyping of these solutions as is done in Engineering; pondering the humanistic and design aspects from the Arts field, from the approach to the problem's solution; while always considering the properties of real-world phenomena, intrinsic to Mathematics. (Maia et al, 2024).

In these learning experiences, students analyze and discuss real-world situations, seeking information that complements their understanding of the phenomenon and guides their actions. Furthermore, exploring everyday problems fosters engagement and a sense of belonging in the learner's community and provides opportunities to think, plan, and implement solutions to the problems addressed, including collaboratively with their peers (Maia *et al*, 2024, p. 3).

According to Pires (2020), pedagogical models for Science Education have been changing, adopting new characteristics over time, increasingly moving away from the passive student model, which prioritizes rote task-solving and memorization. With the current dynamic, more active learning is becoming more important. Science Education is expected to encompass, in addition to conceptual learning, the development of cognitive skills, scientific reasoning, and problem-solving, among other aspects. These aspects align with the STEAM approach, which favors the mobilization of knowledge through authentic problems, especially those related to the students' context.

The STEAM approach considers the integration between areas and the application of concepts in real-life situations. In this sense, it aligns with the vision present in the BNCC, which presents an articulated perspective between Biology, Chemistry, and Physics, aiming to go beyond the learning of conceptual content (Brasil, 2018). Considering the level of difficulty of these components and the importance of their concepts for understanding various everyday phenomena, the investigation and application of approaches such as STEAM, in conjunction with active methodologies such as Project-Based Learning (PBL), stands out as an opportunity to demonstrate the application of scientific content in the search for solutions to real-life problems. In this, as Soares (2023, p. 27) points out, "(...) the knowledge discussed in the curricular components is not dissociated (or compartmentalized), as it is organized in school. In fact, they are united, and their aspects are blended in each phenomenon."

Regarding Mathematics and its integration with other areas, besides occurring naturally within the context, it is reinforced by the presence of the STEAM acronym. Blanco (2020) emphasizes the importance of not viewing Mathematics merely as a tool for the Natural Sciences, but rather recognizing it as necessary for problem-solving, based on questions generated by students. For Lourenço (2024, p. 34), "considering the needs, problems, and local context in which students live redefines their learning, combining contextualized knowledge with the interests of their audience." This form of application is integrated into the historical view of Mathematics, which encompasses not only the application of concepts but also goes beyond, considering the beliefs and values of the people (D'Ambrósio, 2019).

The Modern Mathematics Movement (MMM) in Brazil in the 1960s brought some vulnerabilities to the teaching of Geometry to the present day with its attempt at algebraization (Costa, 2020). One consequence was the sidelining of Geometry teaching in schools for many years, also revealing a lack of pedagogical practices that converse with the skills advocated by Hoffer (1981), namely: (i) Drawing - Ability to interpret ideas by being able to represent them in drawings or diagrams; (ii) Visual - Ability to generate information by observing objects or their representations; (iii) Verbal - Ability to correctly use geometric language; (iv) Logical - Ability to elaborate and judge the validity of formal logical arguments; and (v) Application - Ability to identify, explain and use geometric models in distinct real phenomena (García, 2024). Furthermore, with the levels of Geometric thinking of Van Hiele's model (Leivas & Lutz, 2023; Machado-Júnior, Vieira & Netto, 2022), which seek meaningful and active learning by students. According to Lorenzato (1995), Geometry is the most efficient didactic-pedagogical connection with the different fields of Mathematics and distinct areas of knowledge.

Therefore, the STEAM approach discussed in this article is a strategy that seeks to integrate cultural, social, and emotional components into students' cognitive development in Geometry and Chemistry teaching, correlating them with Biology. This connection was established in this research through a project addressing the environmental issue of combating pigeon infestation in a school sports court, which corroborates similar STEAM projects on environmental issues developed by Roberto *et al* (2021) and Díaz, Rodríguez & Barría (2020).

METHODS

The methodology was qualitative in nature, taking into account the characteristics of the activities produced with the students on a socio-environmental theme with its diverse subjectivities, thus “(...) it avoids numbers, deals with interpretations of social realities, and is considered soft research” (Bauer & Gaskell, 2017, p. 23). This study is an excerpt from the master’s research that used as a methodological strategy the procedures of action research, which is characterized by the collaboration and active participation of the researcher and the participants in favor of solving real problems (Thiollent, 1986). The action research takes place in cycles, composed of several phases that are described in different ways in the literature. In this master's research, the eight phases of the action research cycle presented by McKay and Marshall (2001) were used, namely: 1) Identification of the problem; 2) Literature review; 3) Action planning; 4) Implementation; 5) Monitoring; 6) Evaluation; 7) Improvement; 8) Completion. These phases, which permeate the entire development and evaluation of the project, are illustrated in Figure 1, with the respective implemented actions, highlighting the stages that involve the implementation and evaluation of the project, that is, the focus of the discussions in this study.

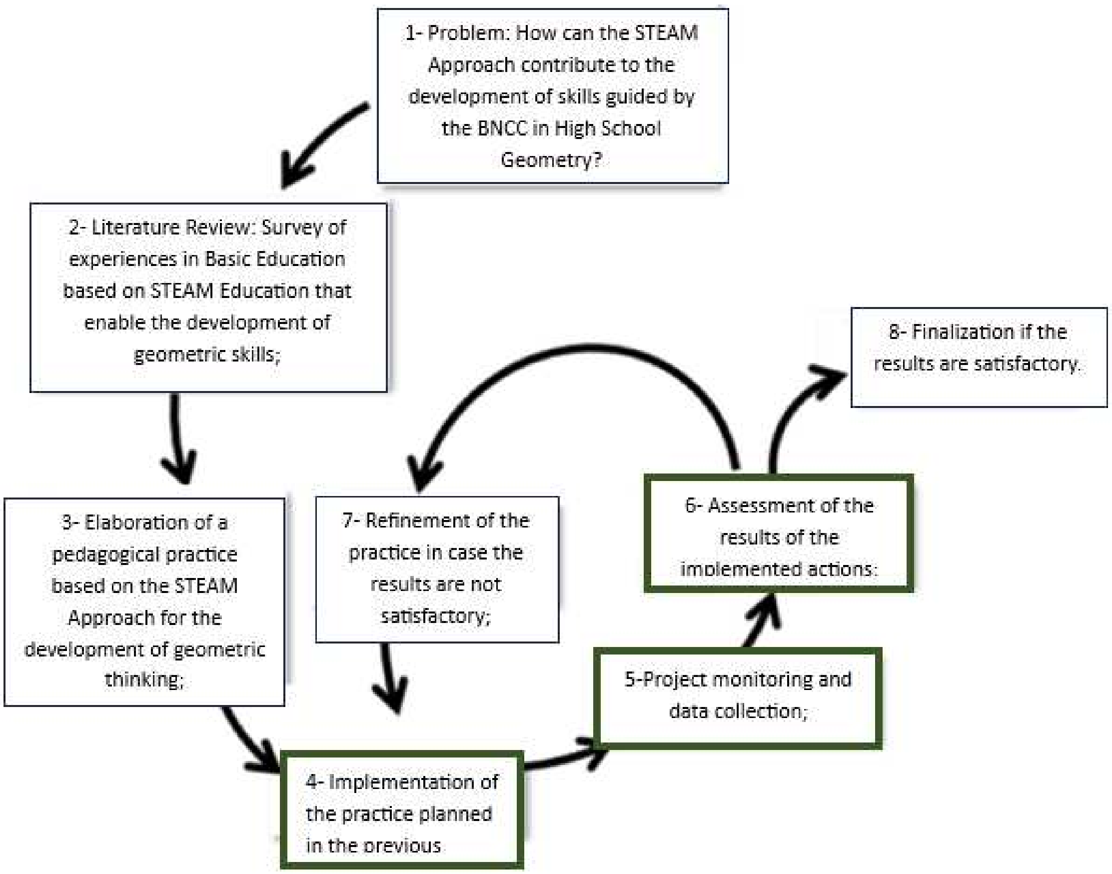


Figure 1. Action research cycle for this study

Source: Adapted from Lourenço (2024).

The pedagogical practices took place at a public school in the North Zone of Natal/RN/BRA, peripheral region of the city, from October to December, 2023. They comprised six meetings and twelve classes in total. This school was taught in the morning shift of the second grade of High School, with 32 students, ages sixteen to twenty, who were scheduled to study Geometry throughout the school year. Two authors of this article acted as teachers, one of Chemistry and the other of

Mathematics. The didactic sequence followed the parameters advocated by Peretti & Costa (2013): a set of activities connected with an educational purpose, which seek to fulfill the objectives planned by the teacher in relation to the learning process of their students.

Furthermore, the PBL active methodology was used, "a teaching model that involves allowing students to confront real-world issues and problems they find significant, determining how to approach them, and then acting cooperatively to find solutions" (Bender, 2014, p. 9). Therefore, PBL helped to delimit each stage of the didactic sequence carried out with the students in the research.

Throughout the project, the characteristic elements of PBL defined by Bender (2014) were used, namely: the presentation of an anchor (a resource chosen by the teacher, such as videos, images, etc.), the collaborative structuring of a driving question — that is, a motivating question of interest to the students — the implementation of group activities, the production of solutions/artifacts, and the public presentation of the results.

These elements are embedded within six stages defined by Bender (2024). Each of these stages was used to subdivide the project's actions. Figure 2 schematically presents these stages and summarizes the project activities developed in each of them.

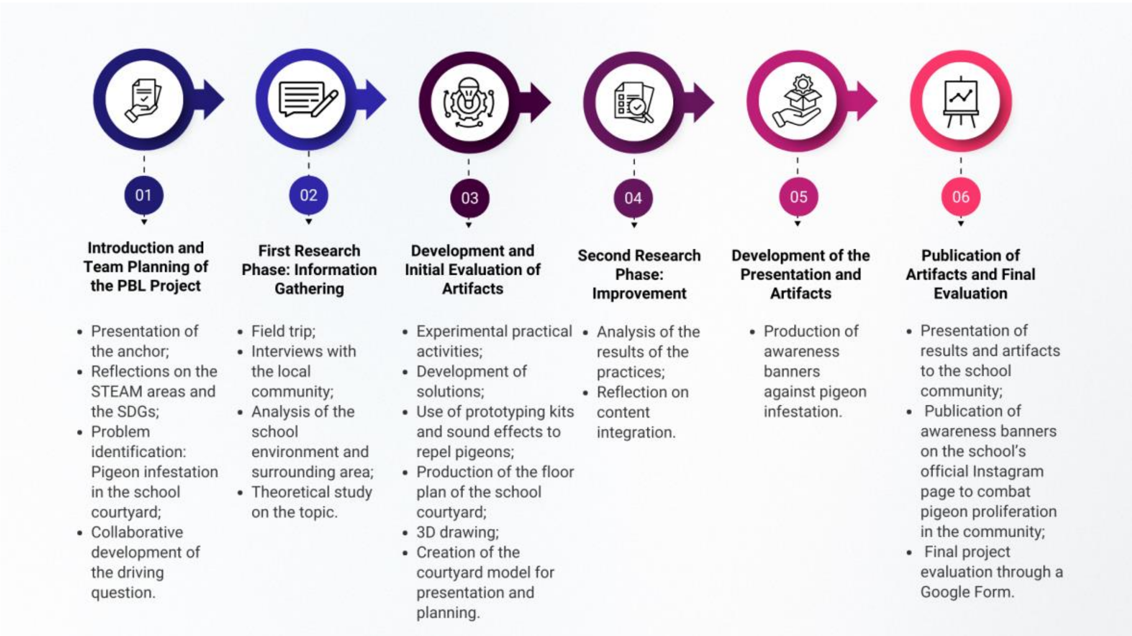


Figure 2. PBL Stages

Source: Adapted from Bender (2014).

As this study represents an excerpt, not all moments of the didactic sequence will be analyzed here. The complete sequence can be found in the teaching guide for teachers, produced as the final work of the research by Lourenço (2024).

Thus, to facilitate the analyses, in this study the stages of the didactic sequence were divided into three moments: (i) Study of pathogens originating from pigeons and analysis of risks to human health; (ii) The importance of Geometry in the search for solutions or investigation of socio-environmental problems in the school community; (iii) Geometry and its transdisciplinarity in the STEAM approach. Table 1 describes the actions and the duration of each phase.

Table 1. Didactic sequence schedule

Phase	Description of the action	Meeting (Duration)
(i) Study of pathogens originating from pigeons and analysis of risks to human health	- Discuss the topic "Pigeons: risk to human health" and how to combat their proliferation in the urban environment (Theoretical and dialogued class).	20/10/2023 (2 classes)
	- Collect a culture of bacteria and fungi in environments with the presence of pigeons (Experimental class).	26/10/2023 (2 classes)
	- Reapply the collection and culture of bacteria and fungi in environments with the presence of pigeons (Experimental class).	07/12/2023 (2 classes)
	- Analyze the collected samples (Theoretical and experimental class).	21/12/2023 (2 classes)
(ii) The importance of Geometry in the search for solutions or investigations of socio-environmental problems in the school community	- Discuss the importance of Geometry in applications of real situations in the school community - Sustainable Garden and Combating the proliferation of pigeons (Expository and dialogued class). - Carry out an activity on the areas of flat figures present on the floor plan of the court provided by SEEC/RN (Practical activity).	07/12/2023 (2 classes)
(iii) Geometry and its transdisciplinarity in the STEAM approach	- Take measurements to discover the contaminated area in the school playground. - Organize the collected data. - Calculate the total contaminated area and its percentage representation (Practical activities).	13/12/2023 (2 classes)

Source: Own authorship (2024).

The first phase, "(i) Study of pigeon-borne pathogens and analysis of risks to human health," focused on the Natural Sciences, discussing the health problems caused by pigeons and the main ways to combat them. The second phase, "(ii) The importance of geometry in finding solutions or investigating socio-environmental problems in the school community," provided an opportunity to discuss the importance of using geometry in real-life situations integrated with the Natural Sciences and its application in student projects, thus integrating the areas of Mathematics and Natural Sciences. The third phase, "(iii) Geometry and its transdisciplinarity in the STEAM approach," included applying geometry to determine the total contaminated area of the schoolyard, connecting other subareas of Mathematics with Mathematics-focused tasks. The BNCC skills mobilized during classes are detailed in Table 2:

Table 2. Skills and Abilities mobilized in the project

Field of Natural Sciences and their Technologies
Skills
EM13CNT205[2] **-** Interpret results and make predictions about experimental activities, natural phenomena and technological processes, based on the notions of probability and uncertainty, recognizing the explanatory limits of science.
EM13CNT301 - Construct questions, develop hypotheses, predictions and estimates, employ measuring instruments and represent and interpret explanatory models, data and/or experimental results to construct, evaluate and justify conclusions when facing problem situations from a scientific perspective.
EM13CNT306 - Assess the risks involved in daily activities, applying knowledge of Natural Sciences, to justify the use of equipment and resources, as well as safety behaviors, aiming at physical, individual and collective, and socio-environmental integrity, being able to make use of digital devices and applications that enable the structuring of simulations of such risks.
Area of Mathematics and its Technologies
Skills
EF05MAT19- Solve and develop problems involving measurements of the quantities length, area, mass, time, temperature and capacity, using transformations between the most common units in sociocultural contexts.
EM13MAT201 - Propose or participate in actions appropriate to the demands of the region, preferably for your community, involving measurements and calculations of perimeter, area, volume, capacity or mass.
EM13MAT314 - Solve and develop problems involving quantities determined by the ratio or product of others – speed, population density, electrical energy, etc.

Source: By the authors based on the BNCC (Brazil 2018).

The data collection instruments consisted of multimedia recordings, photographs, logbook notes, activity applications, and productions developed throughout the investigative and creative practice. All recordings followed the protocols and guidelines of the University Research Ethics Committee because they involved human subjects, with opinion under protocol 71423823.0.0000.5537 approved on September 12, 2023.

RESULTS AND DISCUSSION

The results and discussions were also divided into three main moments, marked by sets of tasks and classes that were connected, the first with tasks focused on the area of Natural Sciences, the second moment with activities integrating

[2] In the Brazilian Common National Curriculum Base, the skills of the curricular components are recorded with codes that indicate: level of education (EM - High School); school grade (13 - from the first to the third grade); curricular component (CNT - Natural Sciences and their Technologies, MAT - Mathematics); skill identification number (#).

Mathematics and Natural Sciences and the third with tasks focused on Mathematics. It is noteworthy that, prior to the moments analyzed here, the stages of student awareness and the selection of the driving question were carried out: "What motivated the pigeons to inhabit the courtyard?" This question was chosen after the students reported a real problem they experienced — the accumulation of pigeons in the school's sports courtyard — which caused several disturbances during classes, such as the presence of droppings, eggs, nests, fallen pigeons, among others, compromising the performance of physical activities, Physical Education classes, and the students' health. Based on this information, a plan was developed to introduce the project's theme and assist students in the search for possible solutions to the problem.

1. Study of pathogens originating from pigeons and analysis of risks to human health

Initially, there was a set of project classes for students integrating the fields of Chemistry and Biology. The Chemistry classes were taught by one of the authors, who was beginning her second undergraduate degree in Biology and collaborated on the research project that gave rise to this section. Thus, several steps and procedures involving the Natural Sciences in general were implemented, which were shared during collective planning with the Math teacher. The activities of the first integration phase were presented and implemented by the Chemistry teacher according to the schedule presented in Table 1 of the methodological path of the pedagogical practice.

The first stage of the schedule began on October 20th with a discussion on the risks pigeons pose to human health. This included a presentation of their origins and main characteristics, as well as a discussion of how they adapted to urban environments, their main predators, and how to combat their proliferation, taking into account the way they are fed by the population, coupled with the food supply in the form of garbage scattered on streets and sidewalks, which contributes to their uncontrolled reproduction. The main diseases that can be transmitted by pigeons, such as *Cryptococcosis*, were also presented. The way these animals live and feed in urban environments—visiting landfills and places with sewage—makes them vectors of mycoses and infections that are dangerous to human health. This fact caused considerable concern among the students due to the high levels of pigeon droppings found in the school sports court environment, which is why they chose this topic to study and dedicate themselves to finding solutions.

This moment helps students understand the topic and context of the problem better, with the support of scientific method. It also allows them to reflect on the impact of human activity on their environment, connecting social and public health issues to school knowledge. Discussing environmental and social issues contributes to the development of critical and reflective citizens. Furthermore, because it addresses a problem affecting the school and community context, it fosters greater interest in the pursuit of knowledge and relevance to the content, a hallmark of STEAM projects.

Subsequently, experimental classes were held on collecting bacteria and fungi in environments where pigeons were present, allowing for the observation and identification of microorganisms present, addressing the technical aspects of creating a culture medium and collection. This experimental activity was conducted based on a script (Table 3) to assist the groups in analyzing the collected samples.

During the analyses, students observed the shape, color, pattern and quantity of colonies present on the plates used, to answer a questionnaire present in the class outline detailed in Table 3.

Table 3. Bacterial culture collection class outline

Practical class	
Bacteria present in environments with the presence of pigeons	
Aim	
Observe the presence of different bacteria in environments with the presence of pigeons, based on the formation of colonies in culture medium.	
Materials	
For the experiments: - Petri dishes; - Cotton swabs; - Masks; - Gloves; - Pen; - Masking tape.	*For the culture medium:* - 100ml of water; - 1 packet of colorless gelatin; - 1 tablet of meat broth; - Bacteria.
Procedure	
STEP 1: Bacteria collection Each group should be responsible for a culture medium. Group members should choose the site for collecting bacteria. Wearing a mask and gloves, one member of the group should apply a cotton swab to the chosen site and gently rub it into the culture medium in the petri dish. One dish should be kept free of bacteria to serve as a control and for future comparisons. After collection, the plate should be closed and sealed with masking tape, and a label should be applied to differentiate the control plate from the other plates. The plates should be stored in a box and stored at room temperature. *STEP 2: Observing the results*	

After a period of four to five days, students should observe whether bacterial colonies have formed, beginning an analysis of the characteristics and comparison with the control plate.
Questionnaire
1) Were colony proliferations observed? If so, on which plates? 2) Characterize the type of proliferation observed. 3) Explain what a culture medium is and what its function is in the experiment. 4) In which of the plates was there the greatest growth? What is the explanation?

Source: Adapted from Lourenço (2024).

On October 26, 2023, students, divided into groups, collected bacterial cultures, following the health and safety guidelines provided by the Chemistry teacher, as shown in Figure 3. After the bacteria proliferation time had elapsed, the students performed the analyses following the script provided in Table 3.

Figure 3. Class participation in collecting bacterial cultures

Source: Lourenço (2024).

In these classes, students were instructed on the importance of careful collection to avoid contamination and realized, in practice, that improper storage caused minor contamination in the control plates, thus hindering the analyses. Furthermore, among the challenges was the difficulty of working with homemade materials such as unflavored gelatin sold in supermarkets. Typically, the culture medium is made with a different gelatin known as agar-agar, which maintains its firmness even when the temperature rises. However, using regular gelatin, after the temperature rises, the culture medium loses its firmness and becomes flaccid, requiring it to be placed back in the refrigerator to firm up. Therefore, the analysis had some limitations within the school context, an experience that allowed students to understand that scientific practice and the investigation of the "S" of Science in the STEAM approach are not predictable. Maia et al. (2024) explains that the use of STEAM involves solving problems using the method and scientific rigor characteristic of the area of Natural Sciences, developing skills and abilities related to this area, associated with the other areas that make up the acronym.

Understanding and analyzing the challenges during the experiment proved to be an opportunity to develop general skills present in the guiding document of the national curriculum, the BNCC, which recommends "Exercising intellectual curiosity and using the approach specific to Science, including investigation, reflection, critical analysis, imagination and creativity, to investigate causes, develop and test hypotheses (...)" (Brasil, 2018, p.9).

It is noteworthy that experimental practice allows students to observe and understand the diversity of microorganisms present in their environment, as well as to practically apply theoretical knowledge about fungi and bacteria. As Pires (2020) points out, "(...) the best way to learn Science is by doing Science, in the sense that to learn something, you have to discover something." Furthermore, during classes, it was possible to address details about these microorganisms, beyond the harm they cause to human health, also identifying their contribution to the environment. As explained by Zappe & Sauerwein (2018), fungi can reduce the nutritional value of food, produce toxins, and cause disease in humans. They are also important in the food industry due to fermentation, in the development of antibiotics, and as decomposers of the biosphere. This context allows us to address the chemical substances involved in the decomposition process carried out by fungi, correlating chemistry and biology.

During the analysis classes, held on December 21st, the discussion about the risks and diseases caused by pigeons was resumed, and the activity the class would carry out using microscopes in the school's Natural Sciences laboratory was clarified, adhering to health and safety standards and measures. Thus, mobilizing the STEAM area represented by the letter "T" for Technology, contributed to the process of analyzing and interpreting the post-collection results, and the BNCC skill EM13CNT306:

> Assess the risks involved in daily activities, applying knowledge of Natural Sciences, to justify the use of equipment and resources, as well as safety behaviors, aiming at physical, individual and collective, and socio-environmental integrity, being able to make use of digital devices and applications that enable the structuring of simulations of such risks (Brasil, 2018, p. 559).

The students reflected on the integration of Chemistry and Mathematics into a single project and found the activity interesting because they had never done anything similar or heard of it being done in any other school they knew. These accounts demonstrate the importance of bringing the humanistic, cultural, and social context—that is, the students' experiences and identities—into the classroom, as reported in D'Ambrósio's (2019) work on the application of the STEAM and Ethnomathematics approach, since learning is stimulated when the learner is engaged. Figure 4 shows the students wearing gloves and masks during the data collection.

Figure 4. Students with health and safety measures accessories

Source: Lourenço (2024).

It's important to note that prior to collection, the culture medium had to be prepared. The class worked with capacity measurement units to prepare the culture medium solution. Later, as the experiment progressed, they observed such rapid proliferation that they became concerned it might occur within themselves. Thus, they were able to recognize the gravity of the situation by connecting various concepts inherent to Biology and Mathematics, such as the proliferation and visual quantification of bacteria through the increase in the area and volume of colonies in the petri dishes used in these classes, revisiting geometric concepts and elements studied in mathematics. Some responses to the activity are described in Table 4.

Table 4. Transcribed responses to the script activity on bacterial culture

Group 1 responses	Group 2 answers
1. Yes, on the plate where students stain bacteria with the cotton swab and the ingredients used to grow bacteria. 2. Characterized by different colors and pigments. 3. The culture medium is generally used to perform chemical analyses. 4. Which had favorable conditions for the growth of the colony, with greater humidity, nutrients and a suitable location.	1. All have proliferation 2. Cryptococcosis 3. The culture medium is the substrate material on which microorganisms are cultivated. It provides all the nutrients necessary for cell growth and survival. 4. Plate 2

Fonte: Adapted from Lourenço (2024).

Based on the students' responses to the questions in the script, the teachers were able to identify possible comprehension issues and subsequently correct the analysis of the signs, based on the questions that arose.

Mathematics was present in the experiment, including the process of preparing the culture medium in the appropriate units of measurement and proportions, as well as the observation of the increase in bacterial colonies on the plates over the determined time, as described by the students in their responses. Therefore, by identifying the STEAM areas represented by the letters "E" and "M" for Engineering and Mathematics, they were able to execute laboratory procedures and ingenuity based on scientific techniques to obtain answers for the activity, using Mathematics to quantify and compare the laboratory results with cases from the outside world. Brazilian research, such as that by Soares (2023) and Roberto *et al.* (2021), demonstrates this integration of Chemistry and Mathematics through the STEAM approach.

The BNCC skills mobilized, as shown in Table 2 of the activities from the first phase of Natural Sciences integration into the project, were: EM13CNT306, which spanned all stages, addressing the assessment of risks involved in daily activities and the application of Natural Sciences knowledge. It also reinforces understanding of the use of scientific equipment and resources, as well as safety behaviors when carrying out experimental activities. EM13CNT301, which highlights skills inherent in students' problem-solving skills, such as questioning, developing hypotheses, predictions, and estimates, strongly interconnects with Mathematics by addressing the use of measuring instruments and "interpreting explanatory models, data, and/or experimental results to construct, evaluate, and justify conclusions when addressing problem situations from a scientific perspective" (Brasil, 2018, p. 559). Finally, EM13CNT205 was mainly present during the analysis phase of the experiment, in carrying out the questionnaire and analyzing the responses, as this skill deals with: Interpreting results and making predictions about experimental activities, using notions of probability and uncertainty as a basis, and recognizing the explanatory and procedural limits present in the stages.

2. The importance of Geometry in the search for solutions or investigations of socio-environmental problems in the school community

The second phase involved a two-class meeting held on December 7, 2023, with the joint participation of the class's Math and Chemistry teachers. The meeting allowed students to delve deeper into the importance of Geometry in real-world applications within the school community. The meeting began with a presentation of a project developed by one of the authors of this paper, based on her master's thesis with another second-year class from the same school. This project, implemented in the first semester of 2023, involved Geometry in the school environment using a STEAM approach. This investigative and creative practice focused on redefining abandoned school spaces through a Sustainable Garden (Soares, 2023), and involved the collaboration of the Math teacher.

One of the objectives of these collaborative classes between teachers was to promote Science in the school environment with the aim of improving students' research and investigative skills.

The class began with the Chemistry teacher highlighting the contributions of Geometry to the school garden, from creating a floor plan, measuring the perimeters and areas of the beds to meet the minimum requirements, measuring the number of *PET* bottles needed to enclose the perimeters of the beds, observing their diameters, and verifying the appropriate distances between rows and plants. Thus, the class aimed to emphasize the importance of integrating Natural Sciences with Mathematics. This explanation sought to broaden the connection between the geometric knowledge learned in mathematics classes and the students' real-life experiences, in this case, based on a project from another class at the school, with the assistance, comments, and observations of the Math teacher when necessary. Pedagogical practices such as these, such as those already mentioned Soares (2023), Roberto *et al.* (2021) and Díaz, Rodríguez and Barría (2020) connect Mathematics to themes related to Environmental Education through the STEAM approach, starting from the context of student life, such as professional experiences or the family environment (D'ambrósio, 2019).

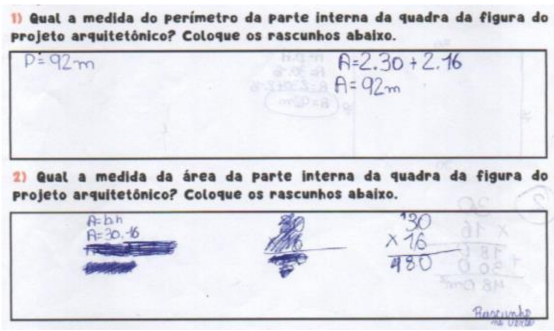
Next, the Math teacher revisited the class project, reviewing some of the students' activities and previously studied geometric relationships. Furthermore, the floor plan of the interior of the sports court provided by the Rio Grande do Norte State Department of Education (SEEC/RN) for use in the class project was presented for the first time.

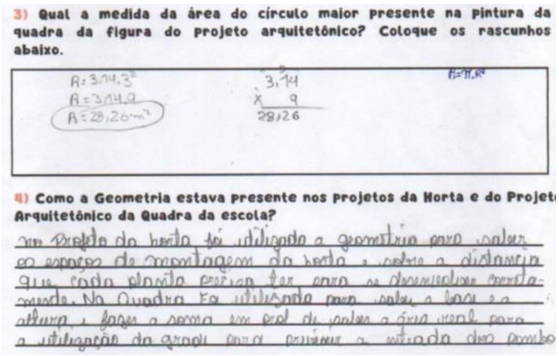
Therefore, the students carried out an integrated activity involving Natural Sciences and Mathematics, which followed the floor plan of the internal part of the sports court, to record the students' perception in relation to the garden project and the application of Geometry in the project to combat the proliferation of pigeons, as shown in Figure 5.

Figure 5. Integrated Chemistry and Mathematics activity moment

Source: Lourenço (2024)

The activity reinforced critical thinking skills and project reflection, as well as spatial measurements, such as the areas of circles and rectangles. Measuring the area of the larger central circular figure on the sports court was developed based on the students' interest in the houseplant pot—a reference to a cylindrical object and its respective circular layout—from the September 25th field trip. It also applied this to radius and diameter, as was also the case in the School Garden project. In this way, the students were able to utilize Hoffer's (1981) Application and Visual Skills, as they identified and interpreted representations of geometric objects, using mathematical models to obtain solutions. Furthermore, measuring the area of the rectangle, which delimits the inner part of the court, would be useful for a future activity to explore the space or area contaminated by pigeon droppings. The students formed groups of five to complete the activity (see Figure 6).





Translation of questions:

1) What is the internal perimeter of the court shown in the architectural design? Place the sketches below.

2) What is the internal area of the court shown in the architectural design? Place the sketches below.

Translation of questions and a student group answer:

3) What is the area of the largest circle in the painting of the school's sports court? Place the sketches below.

4) How was Geometry incorporated into the vegetable garden design and the architectural design of the school's sports court?

In the vegetable garden design, geometry was used to determine the space required for the garden and the distance each plant needs to grow properly. In the playground design, geometry was used to determine the base and height and to calculate the sum to determine the actual area for the use of a fence to reduce pigeon entry.

Figure 6. Answers from a group of the integrated Chemistry and Mathematics activity

Source: Lourenço (2024).

The seven participating groups responded to the activity showing gains in learning, such as in the appropriate use of measurement units, skill EF05MAT19, in Application and Visual Representation, skills addressed by Hoffer (1981), and in the calculation of areas, skill EM13MAT201. The group in the activity above made the draft on the back, as can be seen in Figure 7.

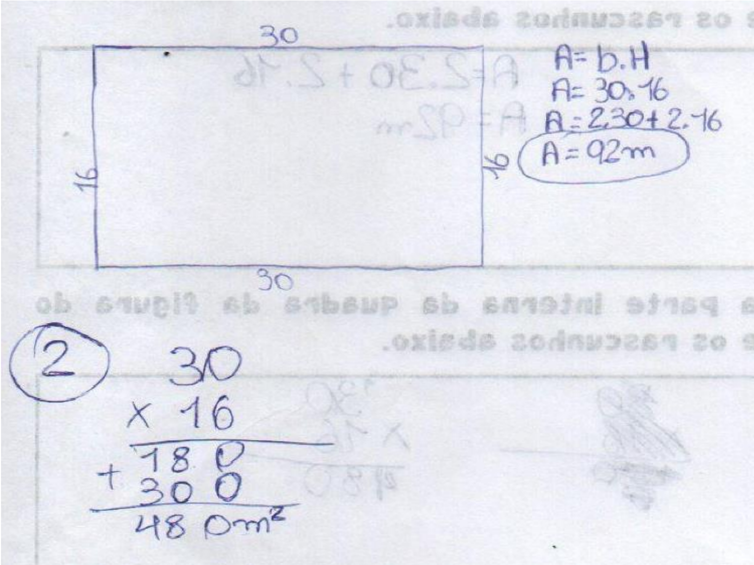
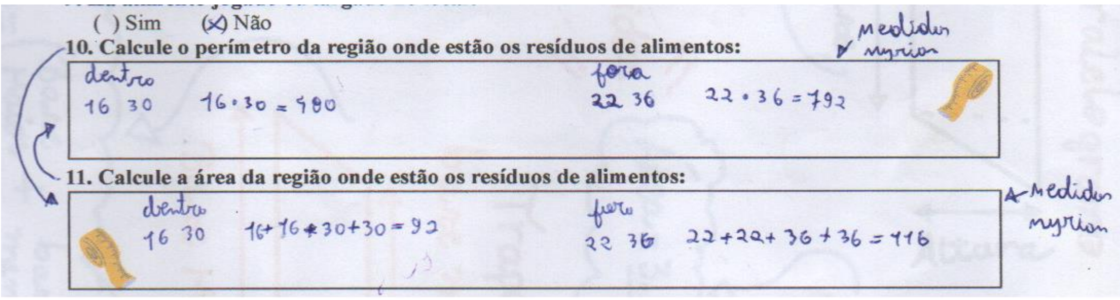


Figure 7. Draft answers from a students group.

Source: Lourenço (2024).

The students demonstrated improvements during the activities, such as organizing ideas in their sketches and visualizing the geometrical aspects of the proposed situations—that is, the Visual and Drawing skills proposed by Hoffer (1981). Furthermore, there was a decrease in errors with the appropriate use of measurement units during their calculations. These points can be verified by comparing the activities, for example, the most recent activity in Figure 7 with another similar, older activity from the field trip, from the same group of students, in Figure 8.



Translation of activity command:

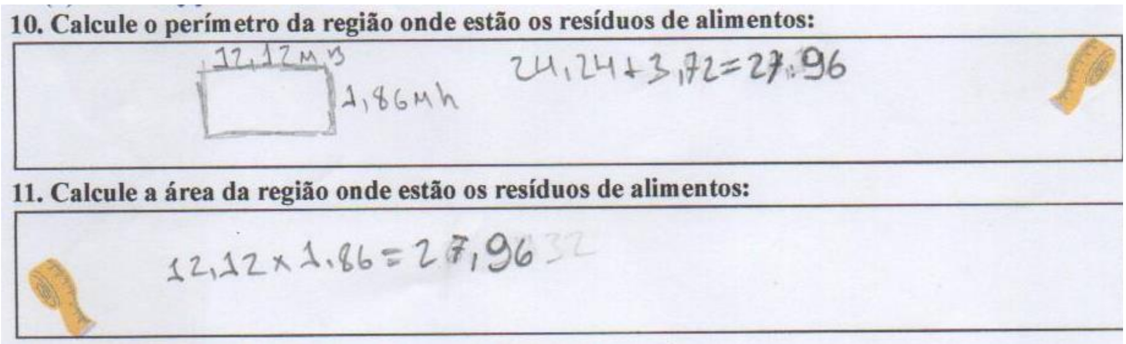
1) Calculate the perimeter of the area where the food waste is located.

2) Calculate the area of the area where the food waste is located.

Figure 8. Draft responses from a group of field class students

Source: Lourenço (2024).

Analyzing the two figures, we can see the difference in the students' organization of ideas and understanding of the problem, in addition to the fact that the construction of the drawing has now become a component of a draft or geometric answer. Initially, in the field trip on September 25th, it was identified that students frequently confused the concepts of perimeter and area in calculations, a situation that no longer occurs. Figure 9 highlights how these errors occurred.


10. Calcule o perímetro da região onde estão os resíduos de alimentos:

12,12 m
1,86 m
24,24 + 3,72 = 27,96

11. Calcule a área da região onde estão os resíduos de alimentos:

12,12 x 1,86 = 27,96

Translation of activity command:

1) Calculate the perimeter of the area where the food waste is located.

2) Calculate the area of the area where the food waste is located.

Figure 9. Draft responses from a group of field class students with errors in the concepts of perimeter and area in the calculations

Source: Lourenço (2024).

Therefore, Figures 8 and 9 show that the student groups were not used to using units of measurement appropriately. Figure 9 also indicates that the group used a single numerical value to represent both the perimeter and area of the area found with food waste accumulation. Furthermore, several groups left the response fields blank, which may indicate that they did not feel confident in the content to complete the activity, requiring further intervention.

However, at the end of the project, the students did not return with the activities without answers, suggesting greater mastery and confidence in the content, and they did not confuse the concepts of perimeter and area in the calculations presented, as shown in Figures 6 and 7.

The STEAM approach brought significant gains in these activities, as in addition to providing the opportunity to work on an authentic and real project for the school community, the letter "S" for Science was present in scientific and investigative thinking in the search for answers and the letter "M" for Mathematics in the use of geometric models and patterns used by students, in parallel.

3. Geometry and its transdisciplinarity in the STEAM approach

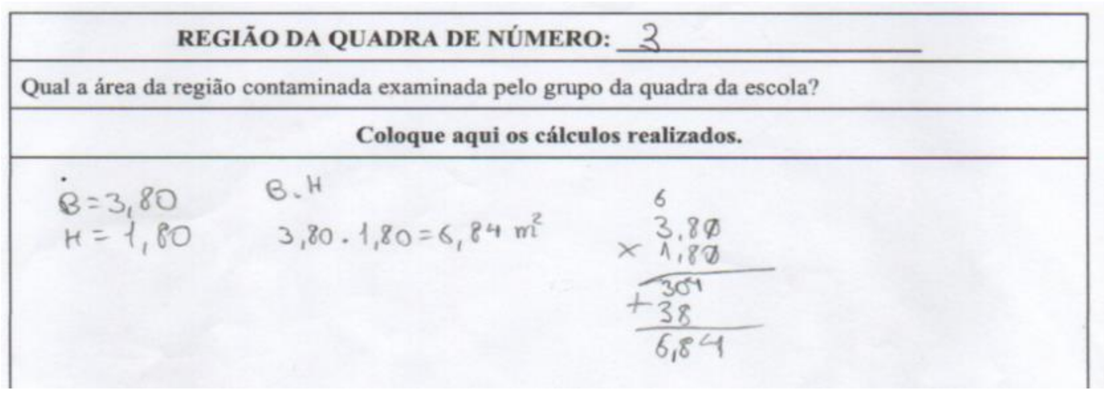
In the third phase, a two-class meeting was held on December 13, 2023, where students analyzed the contaminated area of the sports court. The class performed an activity integrating the percentage applied within a geometric framework, aiming to approximately quantify the area contaminated by pigeons on the school sports court. The students were divided into three groups to take measurements of three distinct regions, as shown in Figure 10.

Figure 10. Students taking measurements on the court of contaminated areas

Source: Lourenço (2024).

The students, already familiar with using the tape measure in other project activities, quickly measured the base and height of the rectangle representation, defining them in the activity's writing, and responded collaboratively with calculations involving the area of the contaminated region corresponding to their group, demonstrating the mobilization of collaboration and communication skills among them.

The responses to the contaminated region activity number three can be seen in Figure 11. In this activity, the students were better able to organize their ideas on paper than in the tasks at the beginning of the project. They did forget some units of measurement, but they no longer confused area with perimeter.



REGIÃO DA QUADRA DE NÚMERO: 3

Qual a área da região contaminada examinada pelo grupo da quadra da escola?

Coloque aqui os cálculos realizados.

B = 3,80 H = 1,80

B . H

3,80 . 1,80 = 6,84 m²

Translation of activity command:

SPORTS COURT NUMBER REGION:

What is the area of the contaminated region, examined by the school's sports court group?

Enter the calculations here.

Figure 11. Contaminated Area Measurement Activity Responses

Source: Lourenço (2024).

Afterwards, the students gathered the collected data with the collaboration of a volunteer colleague to systematize, on the classroom whiteboard, what the class was suggesting, as shown in Figure 12.

Figure 12. Class participation in organizing the collected data

Source: Lourenço (2024).

The students said they should add the areas of the three regions to obtain the total contaminated area. When asked how to determine the percentage of the contaminated area, they immediately suggested using the “rule of three[3]”, using the total area of the court, which had already been calculated in the second step (Figure 13).

They again applied the EM13MAT201 and EM13MAT314 skills, as well as Hoffer's (1981) visual, verbal, drawing, logical, and applied skills. After all, they were able to recognize the figures by their visual particularities, translate information from the problem verbally with appropriate use of geometric language, recognize and draw a geometric figure as a representation of real spaces such as the school court, raise logical and valid arguments in the class's search for a solution to find the total contaminated area and its percentage representation, and apply mathematical procedures and models, respectively. Furthermore, the students marked the activities with their personal identities, as D'Ambrósio (2019) argues, as they are individuals with beliefs and values. So, they drew on the board an image of pigeons defecating and a student wearing a protective face mask. The project's context stemmed from their own interest, which fostered genuine engagement from the entire class. The creativity, proactivity, communication, and collaboration of each student demonstrates that the letter "A" for Arts in the STEAM acronym was also mobilized.

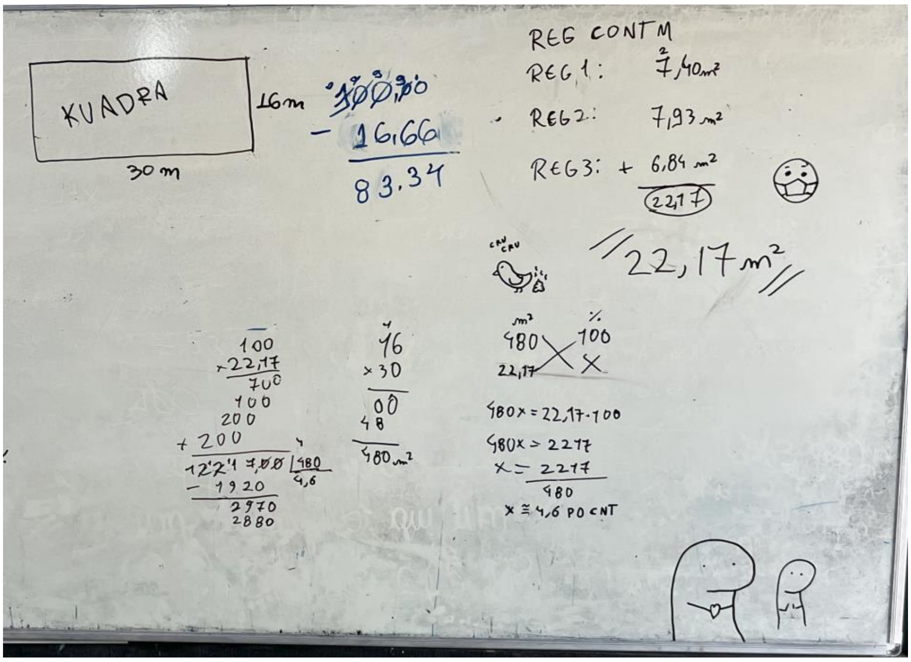


Figure 13. Record the percentage of contaminated area on the whiteboard

Source: Lourenço (2024).

[3] Also called: Proportional Reasoning; Solving Proportions and Cross-Multiplication.

Finally, they concluded that the contaminated area was approximately 4.6%. Although seemingly small, they concluded that the contaminated regions were the areas of greatest ball contact, as they were located in the center of the court and below the basketball hoop, increasing the likelihood of contamination by diseases transmitted by pigeon feces. Thus, the students were able to relate Geometry to probabilistic data, whose integration of subfields of Mathematics was discussed by Lorenzato (1995) when he stated that Geometry is the most efficient didactic-pedagogical connection with distinct areas of mathematics, according to the BNCC, which guides this transdisciplinarity, or STEAM approach, through the integration of different areas of knowledge and highlighting the "M" in Mathematics (Bacich & Holanda, 2020). The integration of STEAM areas plays a significant role in the problem-solving process and in raising students' awareness of the presence of knowledge in their lives. As highlighted by the study of Lourenço *et al.* (2025), which analyzed students' perceptions of this same project, the teacher's role as a mediator in this teaching process is essential for the development of active practices based on the STEAM approach.

Therefore, after this cycle of activities, students had the opportunity to receive support from two areas of knowledge, Natural Sciences and Mathematics, to more fully investigate a problem present in the real world and in the school community.

The artifacts produced by the students throughout the project were several: the floor plan of the school courtyard, the 3D drawing of the courtyard's interior, the model of the courtyard, and the awareness banners. All these artifacts had a specific purpose within the project — to assist in planning and calculating the costs for implementing solutions. The students' performance was evaluated through a rubric that assessed their participation, as well as the development of educational and content-related skills. At the end, self-assessment and project evaluation forms were applied to capture the students' perceptions, the analysis of which can be found in the work of Lourenço *et al*. (2025).

CONCLUSION

This paper analyzed the STEAM approach to teaching Natural Sciences and Geometry in second-grade high school students, applied to a project addressing the problem of pigeon infestation in schools. The study indicated that the partnership between teachers was important for more meaningful, creative, and investigative learning for students. The results showed that the integration of STEAM areas, such as pedagogical practices to combat pigeon infestation involving Mathematics, focusing on Geometry, and Natural Sciences, mobilized Hoffer's (1981) skills of critical thinking, collaboration, communication, and creativity, essential for 21st-century citizens, and also fostered student empowerment.

The conclusion is that the STEAM approach, combined with the active PBL methodology, placed the student at the center of the learning process and provided opportunities for the mobilization of cognitive and socioemotional skills in a relevant application for the school community chosen by the students. The implementation of activities involving investigative and creative practices enabled students to apply their knowledge, allowing them to go beyond theoretical explanations and broaden their perspective on the relevance of academic knowledge embedded in STEAM areas, its connections, and possibilities.

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the author(s).

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