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UNVEILING RESTINGA THROUGH PROJECT-BASED LEARNING: SOCIO-ENVIRONMENTAL ENTREPRENEURSHIP APPLIED TO THE SCHOOL CURRICULUM

DESVENDANDO A RESTINGA POR MEIO DA APRENDIZAGEM BASEADA EM PROJETOS: EMPREENDEDORISMO SOCIOAMBIENTAL APLICADO AO CURRÍCULO ESCOLAR

DESVELANDO RESTINGA A TRAVÉS DEL APRENDIZAJE BASADO EN PROYECTOS: EMPRENDIMIENTO SOCIOAMBIENTAL APLICADO AL CURRÍCULO ESCOLAR

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ABSTRACT

This article analyzes the pedagogical experience "Uncovering the Restinga through Project-Based Learning," conducted with third-year high school students at EEEFEM Domingos José Martins, in Marataízes, Espírito Santo. The objective was to understand how critical Environmental Education, combined with Project-Based Learning (PBL) and the pedagogical language of socio-environmental entrepreneurship, contributes to the appreciation of the restinga and to scientific and civic development. A qualitative and participatory approach was adopted, with classroom problematization, fieldwork in a restinga fragment (demarcation on Google Earth and on-site validations), systematization in a digital portfolio (using Chromebooks and smartphones), and the development of prototypes of socio-environmental startups as pedagogical products. The corpus (forms, reports, photos, notes) was analyzed using Content Analysis. The results demonstrate a shift from initial utilitarian conceptions to an understanding of the restinga as an ecosystem in its entirety (flora, fauna, and geomorphological aspects), consistent evidence of scientific literacy, socio-environmental awareness, and student protagonism in the use of technologies and in proposing contextualized interventions. It is concluded that PBL, when critically reframed and supported by digital tools, promotes meaningful and socially relevant learning, bringing together curriculum, territory, and participation.

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Keywords: Environmental Education. Restinga. Project-Based Learning. Science Education. Socio-Environmental Entrepreneurship. Scientific Literacy.

RESUMO
Este artigo analisa a experiência pedagógica “Desvendando a Restinga por meio da Aprendizagem Baseada em Projetos”, realizada com estudantes do 3º ano do Ensino Médio na EEEFEM Domingos José Martins, em Marataízes/ES. O objetivo foi compreender como a Educação Ambiental crítica, articulada à Aprendizagem Baseada em Projetos (ABP) e à linguagem pedagógica do empreendedorismo socioambiental, contribui para a valorização da restinga e para a formação científica e cidadã. Adotou-se abordagem qualitativa e participativa, com problematização em sala, trabalho de campo em fragmento de restinga (delimitação no Google Earth e validações in loco), sistematização em portfólio digital (uso de chromebooks e smartphones) e elaboração de protótipos de startups socioambientais como produtos pedagógicos. O corpus (fichas, relatórios, fotos, anotações) foi tratado por Análise de Conteúdo. Os resultados evidenciam mudança de concepções iniciais utilitaristas para a compreensão da restinga como ecossistema em sua totalidade (flora, fauna e aspectos geomorfológicos), indícios consistentes de alfabetização científica, sensibilização socioambiental e protagonismo estudantil no uso de tecnologias e na proposição de intervenções contextualizadas. Conclui-se que a ABP, quando ressignificada em chave crítica e apoiada por ferramentas digitais, favorece aprendizagens significativas e socialmente relevantes, aproximando currículo, território e participação.

Palavras-chave: Educação Ambiental. Restinga. Aprendizagem Baseada em Projetos. Ensino de Ciências. Empreendedorismo Socioambiental. Alfabetização Científica.

RESUMEN
Este artículo analiza la experiencia pedagógica "Descubriendo la Restinga a través del Aprendizaje Basado en Proyectos", realizada con estudiantes de tercer año de secundaria en la EEEFEM Domingos José Martins, en Marataízes, Espírito Santo. El objetivo fue comprender cómo la Educación Ambiental crítica, combinada con el Aprendizaje Basado en Proyectos (ABP) y el lenguaje pedagógico del emprendimiento socioambiental, contribuye a la valoración de la restinga y al desarrollo científico y cívico. Se adoptó un enfoque cualitativo y participativo, con problematización en el aula, trabajo de campo en un fragmento de restinga (demarcación en Google Earth y validaciones in situ), sistematización en un portafolio digital (utilizando Chromebooks y teléfonos inteligentes) y el desarrollo de prototipos de startups socioambientales como productos pedagógicos. El corpus (formularios, informes, fotos, notas) se analizó mediante Análisis de Contenido. Los resultados demuestran una transición desde concepciones utilitaristas iniciales hacia una comprensión de la restinga como un ecosistema en su totalidad (flora, fauna y aspectos geomorfológicos), evidencia consistente de alfabetización científica, conciencia socioambiental y protagonismo estudiantil en el uso de tecnologías y en la propuesta de intervenciones contextualizadas. Se concluye que el ABP, al ser replanteado críticamente y apoyado por herramientas digitales, promueve un aprendizaje significativo y socialmente relevante, integrando currículo, territorio y participación.

Palabras clave: Educación Ambiental. Restinga. Aprendizaje Basado en Proyectos. Educación Científica. Emprendimiento Socioambiental. Alfabetización Científica.

1 INTRODUCTION

Environmental Education has been gaining centrality in the Brazilian educational debate, especially in the face of the worsening socio-environmental crisis and development models that put pressure on the commons. At the normative level, the National Policy on Environmental Education and recent curricular guidelines reinforce the obligation to treat the theme as a formative dimension at all levels of education. In Espírito Santo, curriculum documents guide that the area of Sciences be worked on in a contextualized way, with the territory as a reference for learning.

Despite this regulatory advance, there remains a mismatch between what is prescribed and what is experienced at school. In many classrooms, the contents appear fragmented and poorly connected to the local reality, which makes it difficult for students to recognize problems and potentialities of the place where they live. It was exactly this distance between guidelines and practice that was evident in the context of this investigation.

The analyzed proposal was born in a high school Biology class, during the work with the ecosystems curricular content. The restinga was presented as an example of typical formation of the Atlantic Forest. When provoking the class on the topic, statements such as "those little bushes", "a boardwalk would be better" and "this vegetation disturbs the beach" emerged. Even the most favorable answer, "this vegetation is important for the sea not to advance", indicated an understanding restricted to a utilitarian function. The contradiction was evident: the school is a few meters from a fragment of degraded sandbank, but this environment remained invisible to the students.

In view of this situation, critical Environmental Education was assumed as a formative horizon. The objective was to shift the focus from isolated individual attitudes to the understanding of socioeconomic and political relations that produce degradation, favoring broader readings of the territory and school daily life. This orientation sought to "uncover the eyes" of the students, inviting them to perceive the restinga as a socio-environmental heritage and not as an obstacle to leisure.

To give shape to the work, Project-Based Learning was adopted as an organizing strategy and was re-signified in a critical key. Instead of being reduced to a sequence of tasks, the methodology structured a situated investigation: problematization in the classroom, fieldwork in the fragment near the school, systematization of data and feedback to the school community. The dialogue with the language of socio-environmental entrepreneurship made it possible to transform the findings into prototypes of startups understood as pedagogical

products, not as a market initiative, but as an exercise in proposing responsible and contextualized solutions to value and conserve the restinga.

Thus, the general objective of this article is to analyze how critical Environmental Education, in dialogue with Project-Based Learning and with proposals for socio-environmental innovation, can contribute to the valorization of the restinga and to critical education in High School.

1.1 SPECIFIC OBJECTIVES:

1. Identify the students' initial conceptions about the restinga from classroom discussions and guided records.
2. To analyze how critical Environmental Education guided the problematization of the territory and the reflection on the local reality.
3. Describe the application of Project-Based Learning in the pedagogical path, highlighting stages and mediations.
4. Evaluate the learning results from the products prepared by the groups and their contribution to the valorization of the restinga.

2 THEORETICAL FRAMEWORK

The theoretical framework that supports this study brings together contributions from critical Environmental Education, Science teaching and contemporary pedagogical approaches, also dialoguing with the concept of socio-environmental entrepreneurship. The intention is to articulate different perspectives without losing sight of the fact that each of them is based on different foundations and, in some cases, even tensioned with each other. On the one hand, critical Environmental Education denounces the social contradictions that feed the socio-environmental crisis and defends a transformative educational practice, guided by ethical and political values. On the other hand, methodologies such as Project-Based Learning offer ways to organize pedagogical work around real problems, promoting student protagonism and collaboration. The notion of entrepreneurship, when resignified in a socio-environmental key, can bring students closer to creative processes that result in intervention prototypes committed to sustainability. In this context, the restinga, as a local ecosystem, is configured not only as an object of study, but as a pedagogical territory in which science, society and the environment are articulated.

2.1 CRITICAL ENVIRONMENTAL EDUCATION: MACRO TRENDS AND CHALLENGES

Environmental Education (EE) in Brazil has consolidated a plural field, with different theoretical and political orientations. Layrargues and Lima (2011) systematize three macro trends: the conservationist, centered on the protection of natural resources through behavioral changes; the pragmatic, oriented to environmental management and the idea of sustainability as efficiency; and criticism, which interprets the socio-environmental crisis as an expression of historical, economic, and political contradictions and, therefore, proposes social transformation with socio-environmental justice and citizen participation. It is in this last aspect that this study is anchored.

Critical EE understands education as a transformative praxis and not as a mere transfer of ecological information. Freire (2005) inspires this horizon by conceiving education as a process of reading the world, dialogue and emancipation. Guimarães (2004) highlights that training environmentally critical educators and students implies articulating ethical, political and technical dimensions, facing individualizing reductionism. Loureiro (2012) reinforces that EE only fulfills its function when it promotes collective values, participation and responsible intervention in the territory.

There is consensus on the need to think about EE beyond ecological moralism and technicality. Tensions persist, however: difficulties in transposing critical references to school practices pressured by content-based curricula, short times and performance expectations. This work dialogues with this scenario by assuming critical EE as an axis and by seeking pedagogical mediations that make sense in the daily life of public schools, taking the territory of the restinga as an object and place of learning.

2.2 SCIENCE TEACHING, SCIENTIFIC LITERACY AND CURRICULUM

The teaching of Science, especially in High School, faces the challenge of overcoming fragmented practices that are centered only on the transmission of content. Delizoicov, Angotti and Pernambuco (2011) argue that this teaching should be structured based on problematization, understood as the creation of situations in which the student is invited to reflect on real and socially relevant issues. This movement breaks with the encyclopedic view of the discipline and allows science to be understood as a human construction, historically situated and in permanent transformation.

In this horizon, Chassot (2000) proposes the notion of scientific literacy, which goes beyond the domain of technical concepts and terms. To become scientifically literate is to

offer conditions for subjects to read the world, interpret everyday phenomena and take a critical position in the face of contemporary dilemmas, including social inequalities and the socio-environmental crisis. This perspective is close to Freire's (2005) contributions, when he emphasizes that knowledge only gains meaning when it enables a critical reading of reality and is articulated with transformative practice.

From the point of view of curricular policies, this understanding is present in the National Common Curricular Base (BNCC), which establishes that the teaching of Science must integrate investigation, contextualization and student protagonism (BRASIL, 2018). The Espírito Santo Curriculum reinforces this direction by highlighting that the contents must be worked on in an articulated way with territorial specificities, enabling the understanding of local ecosystems and their challenges (SEDU/ES, 2020). Both documents, therefore, converge on the need to value the territory and the cultural context as structuring axes of pedagogical practice.

In the case of this study, the restinga presents itself as a living curricular content, which allows students to recognize the presence of science in their daily lives. By shifting the attention of the books and pictures to a real fragment of restinga located in the vicinity of the school, the proposal brought theory and practice closer together, favoring scientific literacy in its broadest dimension: understanding science as a tool for interpreting reality and as a path to social transformation. In this sense, the teaching of Science is no longer just a school subject to become a space for critical reading of the world and training for socio-environmental citizenship.

2.3 PROJECT METHODOLOGIES: POSSIBLE APPROXIMATIONS

The school has faced the challenge of motivating students in a context marked by the abundance of information and the need to develop skills beyond the memorization of content. In this scenario, Project-Based Learning (PBL) emerges as a pedagogical alternative capable of bringing teaching closer to the students' reality and giving greater meaning to the curriculum.

In its current formulation, as systematized by Bender (2014), it is characterized by the organization of activities around authentic issues, in which students investigate, collaborate in teams, use different sources of information and build a product that synthesizes the learning process.

One of the hallmarks of PBL is the centrality of student protagonism. Students are no

longer passive receptors of content and assume the role of researchers, while the teacher acts as a mediator, guiding the path and ensuring conceptual depth. This process involves well-defined steps, such as: definition of the guiding question, planning of actions, research in different sources, preparation of records and socialization of the results (MUNHOZ, 2015).

For Moran (2018), PBL also gains strength when articulated with digital technologies, which expand the possibilities of authorship and communication. The use of applications, platforms and multimedia resources favors the curation of information and gives greater visibility to student productions, bringing the school closer to new learning ecologies.

However, it is worth noting a critical point. PBL, when applied in a decontextualized way, can be reduced to a set of tasks that, although involving, do not promote reflection or transformation. Therefore, we argue that it is always necessary to resignify a methodology, in this case, articulating it with critical Environmental Education, so that projects are not only instruments to meet goals, but opportunities to problematize social and environmental contradictions.

It was in this perspective that the experience reported here developed. PBL was used as a strategy to bring students closer to the reality of the restinga, allowing them to investigate their territory, produce records, discuss data and collectively elaborate intervention proposals. In this way, the methodology was not treated only as an innovative pedagogical resource, but as a formative process that contributed to the development of scientific literacy and socio-environmental awareness.

2.4 SOCIO-ENVIRONMENTAL ENTREPRENEURSHIP: PROTOTYPES AS PEDAGOGICAL PRODUCTS

The discussion about entrepreneurship has historically been marked by the logic of the market, oriented towards the creation of businesses and competitiveness. However, we seek possibilities to reframe this concept in a socio-environmental key, aimed at promoting sustainability and seeking collective alternatives to local problems. Dornelas (2018) reminds us that entrepreneurship is, above all, transforming ideas into actions, and when this movement is guided by ethical values, the potential to contribute to significant social and environmental changes is expanded.

In the field of innovation, Ries (2012) presents the concept of *lean startup*, which emphasizes rapid cycles of experimentation, validation and course correction. This proposal enables a simpler transposition to the school environment. Which can favor learning

processes in which students take the risk of proposing solutions, testing them on a small scale and rethinking them creatively. SEBRAE (2017) also recognizes the importance of working on the entrepreneurial spirit at school, stimulating creativity and youth protagonism, although with greater emphasis on preparing for the market.

In the reported experience, these references were reinterpreted in a pedagogical key. The objective was not to train entrepreneurs, but to enable students to experience the creation of prototypes of socio-environmental startups as educational products. Such prototypes worked as learning instruments, allowing young people to investigate real problems related to the restinga and present intervention proposals, such as community monitoring, alternatives to the use of plastics, sustainable tourism itineraries and educational campaigns.

This choice dialogues with the context in which we live, marked by capitalist dimensions that influence school daily life and social life. When proposing the creation of prototypes, the need to familiarize students with a current language is recognized. However, this exercise was conducted from a critical perspective, which sought to shift the emphasis from profit to socio-environmental responsibility. Thus, the products elaborated were not configured as simply a marketing enterprise, but as creative proposals for social intervention, aimed at valuing and conserving the restinga and its social integrating aspects.

In this way, socio-environmental entrepreneurship, re-signified in an educational key, fulfilled a mediation role: at the same time that it dialogued with contemporary demands, it opened space for the formation of critical subjects, capable of thinking of innovative solutions that unite science, environment and society.

2.5 THE SANDBANK AS A LEARNING SPACE

Restingas are coastal plant formations that are part of the Atlantic Forest biome, characterized by sandy soils, high luminosity, constant winds and unstable water regime, conditions that select adapted species and confer high floristic heterogeneity (ARAÚJO; HENRIQUES; MEIRELES, 1984; SCARANO, 2002). These ecosystems fulfill essential ecological functions, such as the protection of the coastline against erosive processes, the maintenance of aquifers, and the provision of habitats for endemic and endangered species (MAGNAGO; MARTINS; PEREIRA, 2011).

Despite this relevance, the restingas are among the most vulnerable environments in the Atlantic Forest. Anthropogenic pressures such as urban expansion, real estate

speculation, opening of roads and disorderly tourism have resulted in loss of biodiversity, fragmentation and decharacterization of landscapes (RODRIGUES; LIMA, 2020; PEIXOTO; PEREIRA, 2006). The situation is even more serious in the coastal municipalities of Espírito Santo, where fragments of restinga survive in the midst of degradation and social invisibility. This picture confirms the diagnosis of Scarano (2002), according to which the restinga occupies a paradoxical position: on the one hand, it constitutes a natural heritage of high value; on the other, it remains socially devalued, often associated with "vacant lots" or "useless bushes".

In the educational field, this invisibility is reflected in the students' lack of knowledge about the importance of the restinga, even when they live with it on a daily basis. Transforming this space into an object of study means resignifying it as a pedagogical territory, bringing the teaching of Science closer to the local reality and creating opportunities for critical learning. This perspective dialogues with the BNCC (BRASIL, 2018) and the Espírito Santo Curriculum (SEDU/ES, 2020), which guide work with content linked to the territory and the integration between science, culture and citizenship.

In addition to an ecosystem, the restinga is a social and cultural space, as its occupation is linked to political and economic choices. When it is incorporated into the curriculum, it becomes a fertile field for critical Environmental Education, allowing us to problematize how the logic of capitalist urban development threatens natural environments and coastal communities (LOUREIRO, 2012; LAUREL; LAYRARGUES, 2013). Working with the restinga in the classroom favors the perception that conservation is not only about maintaining species, but also about questioning models of use and appropriation of the territory.

School experiences linked to Science clubs, pedagogical gardens, and institutional programs, such as the Rio Doce Escolar Program (2022), have demonstrated the power of educational projects that articulate territory and critical education. As part of this movement, the experience *"Unraveling the Restinga"* sought to resignify a degraded local fragment as a space for discovery and scientific investigation. More than transmitting information about ecology, the work promoted in the students a process of critical reading of reality, encouraging them to propose alternatives for valuing and conserving this environment.

Thus, the restinga has consolidated itself not only as an object of study, but as an integrated learning space, where science, society and environment are intertwined. When it was brought to the curriculum, it was no longer seen as a worthless "bush" and began to be

recognized as a fundamental socio-environmental heritage for coastal life.

3 METHODOLOGY

3.1 RESEARCH APPROACH

The study adopted a qualitative and participatory approach, aimed at understanding meanings, perceptions and learning constructed by the students throughout the pedagogical intervention. This option is appropriate when the focus falls on formative processes in real teaching contexts, privileging interpretation, dense description, and internal coherence of the procedures (GIL, 2018; MOREIRA; CALEFFE, 2008). The student participation took place in the problematization, in the fieldwork, in the systematization and in the socialization of results, characterizing an investigative path that takes the territory as an educational reference.

3.2 CONTEXT OF THE RESEARCH

The experience took place at the Domingos José Martins State School of Elementary and High School, located in Marataízes, Espírito Santo. The institution is located near a fragment of restinga in the process of degradation, a circumstance that evidenced the contradiction between geographical proximity and pedagogical invisibility of the ecosystem. This context motivated the intervention focused on the critical reading of the territory and the articulation between curriculum, science and society.

3.3 PARTICIPANTS

Students from the 3rd year of High School participated, with the mediation of the Biology teacher responsible for the class. The professor organized the route, planned the recording instruments and conducted the necessary mediations to ensure conceptual rigor, safety in the field and public feedback on the work. No personally identifiable data was collected; The statements used for exemplification were recorded anonymously.

3.4 ORGANIZATION OF RESEARCH GROUPS AND THEMES

To broaden the angle of analysis and ensure an integrated look at the restinga, the class was organized into four thematic groups, each with a specific field sheet:

- **Group 1 — Restinga vegetation**
  - Observation of plant species and formations; record of adaptations to sandy soil and salinity; relationships between vegetation cover and substrate stability. Examples of

card items:

- Main forms of plant life identified.
- Visible adaptations (Example: leathery leaves, deep roots).
- Hypotheses about the ecological function of vegetation in the place.
- **Group 2 — Restinga fauna**
- Direct and indirect observation of animals (birds, insects, reptiles); footprint and nest records; trophic links with vegetation. Examples of items:
- Observed taxa and indirect evidence.
- Perceived fauna-flora relationships.
- Possible anthropogenic impacts on fauna.
- **Group 3 — Environmental impacts**
- Survey of anthropogenic pressures and signs of degradation (garbage, removal of vegetation, erosion associated with trampling and occupations). Examples of items:
- Mapped impact types and location.
- Likely consequences for biodiversity and coastal dynamics.
- Initial mitigation proposals.
- **Group 4 — Geomorphology of the restinga**
- Recognition of the sandy substrate, micro-reliefs, evidence of transport and deposition; relationship between physical features and vegetation cover. Examples of items:
- Soil characteristics observable with the naked eye.
- Indications of sand mobility and stabilization.
- Relationship between physical features and the presence of plants.

This division ensured a total look at the ecosystem, avoiding fragmentation between "content" and reality.

3.5 STAGES OF DEVELOPMENT

The methodological path was structured in five linked stages, organized under the logic of Project-Based Learning (BENDER, 2014), resignified in a critical key:

3.5.1 Problematization in the classroom

The theme emerged during the "ecosystems" content, when the students' lack of knowledge about the restinga was evidenced, expressed in statements such as "those little

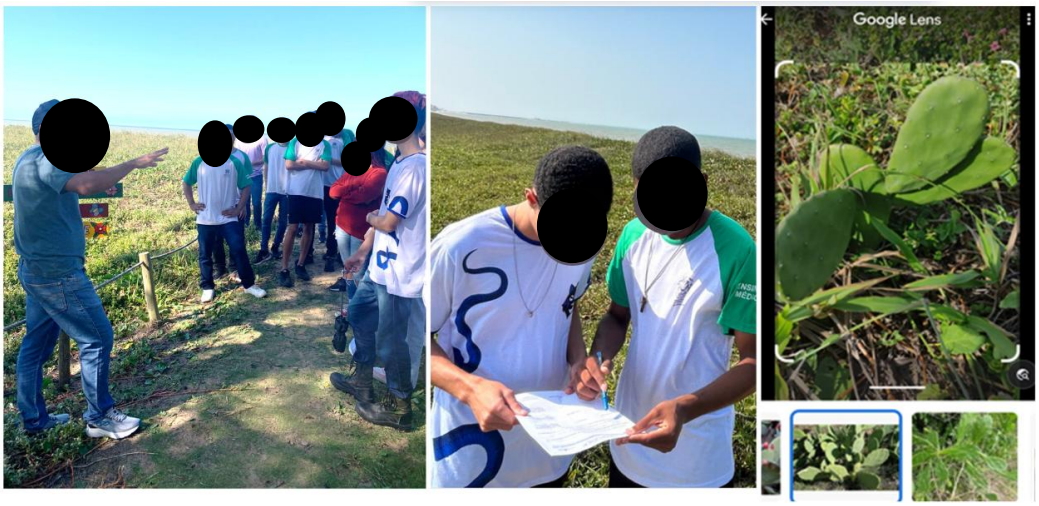
forests" and "this vegetation disturbs the beach". This diagnosis guided the project's guiding questions.

3.5.2 Fieldwork on the restinga fragment

The groups applied their forms, made photographic records and collected evidence, observing vegetation, fauna, impacts and geomorphological aspects. The teacher accompanied the activities, ensuring safety, focus and rigor in observation.

Figure 1

Fieldwork in the sandbank



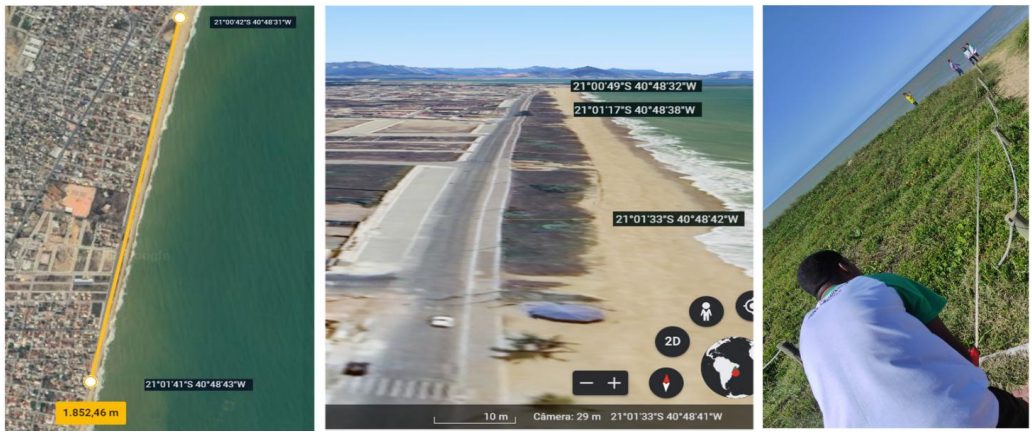
Source: Researchers' collection (2024).

Figure description: (a) initial orientation of the teacher to the class; (b) students filling out the field form; (c) preliminary identification of plant species with Google Lens.

Delimitation of the section studied. To define the spatial cutout of the study, Google Earth (web) was used. The extreme points of the restinga fragment located in Marataízes, ES, were marked: Point A = 21°00'42"S; 40°48'31"W and Point B = 21°01'41"S; 40°48'43"W. (Coordinates in decimal degrees: A = −21.011667; −40.808611 and B = −21.028056; −40.811944; datum WGS-84, Google Earth standard.) The linear distance between the points, measured on the platform itself, was 1,852.46 m (see Figure 7). In the field, the team validated this tracing through transects with a tape measure, ensuring correspondence between the digital cutout and the area actually observed.

Figure 2

Delimitation of the restinga fragment analyzed



Source: Google Earth; Accessed on: 23 ago. 2024. Researchers' collection (2024).

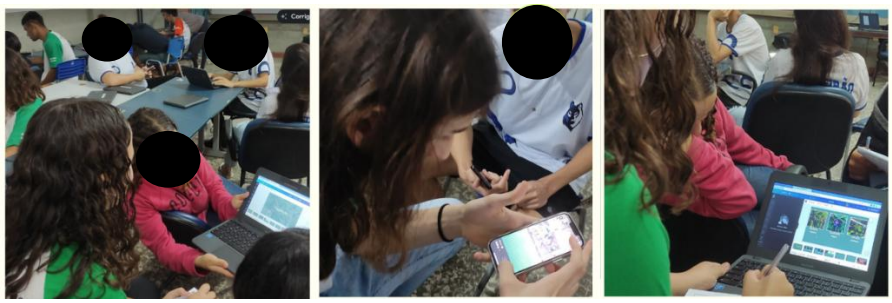
Figure description: (a) layout and extension of the stretch in Google Earth (1,852.46 m); (b) oblique view with coordinates; (c) on-site measurement with a tape measure along the transect.

3.5.3 Systematization of data at school

Organization of material in group reports and collaborative digital portfolio. The teams used digital tools to support the analysis, with emphasis on Google Lens (preliminary identifications in flora) and Google Earth (spatial reading and location of the fragment).

Figure 3

Systematization of data in the school



Source: Researchers' collection (2024).

Figure description: (a) elaboration of the digital portfolio on chromebook; (b) checking records and Figures on a smartphone; (c) collective organization of the evidence collected.

3.5.4 Preparation of prototypes of socio-environmental startups

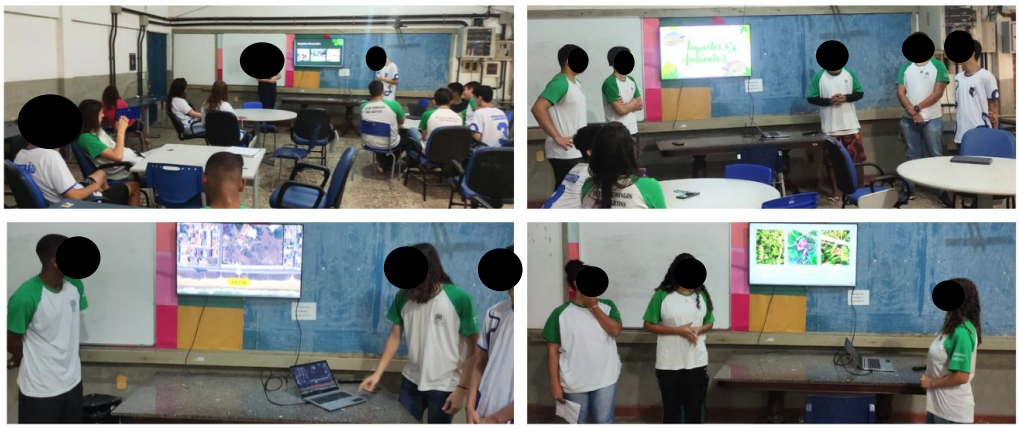
Based on the findings, each group structured intervention proposals in prototype format (community monitoring, sustainable visitation itineraries, alternatives to plastics, educational campaigns), treated as pedagogical products from a perspective of entrepreneurship with socio-environmental responsibility.

3.5.5 Socialization of results

There were two moments for the socialization of the results and presentation of proposals for possible socio-environmental Startups. The first moment was a presentation to the class and teacher, in a perspective of peer validation. The following Figures show, in order, the groups: a) Fauna Group; b) Anthropic Impacts Group; c) Geomorphology Group; d) Flora Group.

Figure 4

Presentation of the groups, peer evaluation

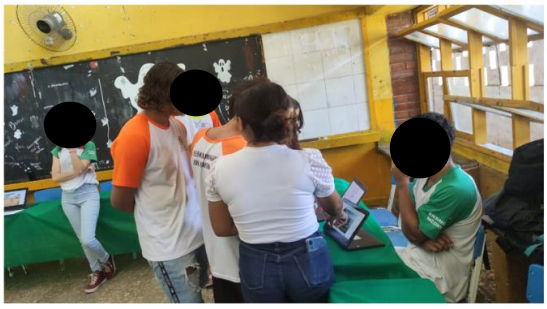


Source: Researchers' collection (2024).

The second moment was a presentation to other classes and teachers of the School. This stage consolidated the social character of learning and expanded the circulation of the knowledge produced.

Figure 5

Socialization of results at school



Source: Researchers' collection (2024).

3.6 INSTRUMENTS OF RECORD

Complementary instruments were used:

- Field sheets differentiated by group (vegetation, fauna, impacts, geomorphology);
- Photographic records made by the students;
- Reports written by the team, with synthesis of findings and conceptual references worked on in class;
- Collaborative digital portfolio, bringing together captioned photos, maps and transcriptions of relevant excerpts;
- Teacher's notes, recording speeches, doubts and inferences formulated by the groups during the course.

3.7 ANALYSIS PROCEDURES

The data were organized and interpreted through Content Analysis (BARDIN, 2011), in three movements:

3.7.1 Pre-analysis

Floating reading of files, reports, portfolio and notes; definition of the registration units (speeches, field descriptions, justifications of the prototypes) and context units (group memorials and syntheses).

3.7.2 Exploitation of the material

Coding by nuclei of meaning associated with the objectives of the study.

Table 1

Analytical categories and their descriptors

Analytics Category	Descriptors (nuclei of meaning)
Initial conceptions about the restinga	utilitarianism; invisibility; unique function.
Contributions of Critical Environmental Education	territorialization of the problem; socio-environmental articulation; collective accountability.
PBL as an investigative strategy	Role; use of technologies; field-room integration.
Social and environmental prototypes	pertinence to the diagnosis; educational feasibility; potential for awareness.

Source: Prepared by the authors

3.7.3 Treatment and interpretation

Organization of categorical matrices and elaboration of inferences articulating empirical evidence and theoretical framework (Delizoicov et al., 2011; Bender, 2014; Loureiro, 2012; Layrargues; Lima, 2011). The categories served as the architecture for the "Results and discussion" section.

The coded occurrences were consolidated into category × source × evidence matrices, with analysis of frequency and competition between descriptors. Representative excerpts and negative cases were selected to support the inferences. Triangulation was carried out between instruments and moments of the research, crossing files, portfolios, field descriptions, justifications of the prototypes, group memorials and syntheses. To reinforce reliability, an independent double reading of a sample of the corpus was performed, with a record of the analytical decisions in the audit trail. The interpretations were produced by a progressive approximation between empirical evidence and theoretical framework, preserving the alignment with the objectives and the criterion of thematic saturation for the end of the analysis. The results of this treatment support the "Results" and "Discussion" sections, maintaining the anonymity of the participants.

3.8 ETHICAL CONSIDERATIONS AND LIMITATIONS

The research followed ethical principles of research in education. Student participation was voluntary, with authorization from the school board and science from the pedagogical sector. All speeches were anonymized and the material was used exclusively for educational and scientific purposes.

As limitations, the focus on a single class and a single fragment of restinga is recognized, which restricts the generalization of the findings. In qualitative research, however,

transferability is sought based on the description of the procedures (MOREIRA; CALEFFE, 2008). Replication in other classes and coastal schools emerges as a way to increase comparability.

4 RESULTS AND DISCUSSIONS

4.1 RESULTS

4.1.1 Students' initial conceptions

In the problematization in the classroom, utilitarian and invisible perceptions of the restinga emerged. Oral records included: "matinhos", "a boardwalk would be better", "it disturbs the beach". Even the speech "hold the sea" kept an exclusive focus on a practical function. This diagnosis guided the guiding questions and the design of the field.

4.1.2 Fieldwork and awareness raising

In the delimited fragment (Marataízes, ES; 21°00'42"S–40°48'31"W to 21°01'41"S–40°48'43"W), the groups recorded:

- Vegetation: herbaceous/shrubby forms adapted to the sandy substrate; leathery leaves; robust roots.
- Fauna: direct/indirect observation of birds and insects associated with vegetation.
- Impacts: garbage, trampling, removal of plants, erosion in stretches of intense use.
- Geomorphology: loose sandy soil; importance of vegetation cover for sand stabilization.

The visual evidence and reports are illustrated in Figures 6–8 (on-site orientation, use of Google Lens, delineation with Google Earth and transect measurements).

4.1.3 Systematization and application of PBL

Back at school, teams systematized data into reports and digital portfolio, employing Chromebooks and smartphones (Figure 8). The PBL structured the course in: problematization → field → analysis → prototyping → socialization. Each group elaborated syntheses and justifications based on the forms, photos, internet research and references indicated by the Professor.

4.1.4 Prototypes of socio-environmental startups and socialization

Based on the diagnosis, the groups presented prototypes (Figure 9) as pedagogical products, focusing on:

- Community monitoring of the restinga (awareness and reporting of impacts);
- Alternatives to plastics (bioproducts) and responsible consumption;
- Sustainable tourism itineraries with environmental education;
- Educational campaigns for school and community.

The presentations among peers favored argumentation, feedback to the school community and visibility of the ecosystem.

4.1.5 Evidence of learning

- **Scientific literacy:** all students showed evidence (use of observations to explain phenomena; link between vegetation and sand stabilization; fauna-flora relationships; reading of maps and coordinates).
- **Socio-environmental awareness:** recognition of anthropogenic causes of impacts and the need for collective actions.
- **Valuing the restinga:** understanding as an ecosystem in its entirety, not just a barrier against the sea.
- **Student protagonism:** authorship in the use of digital tools and in the proposition of solutions.

4.1.6 Summary of results

Table 2

Summary of results by category

Category	Observed indicators	Key evidence
Early conceptions	utilitarianism; invisibility	"matinhos"; "Boardwalk"
Countryside (vegetation/fauna)	Adaptations; Interactions	Pictures; Chips; Google Lens
Field (impacts/geomorphology)	garbage/erosion; sandy soil; Stabilization by the flora	Figures; Measurements; Notes
ABP and technologies	digital portfolio; collaboration	Chromebooks; Earth; records
Prototypes	Monitoring; bioproducts; tourism; Campaigns	Posters; Presentations
Learning	scientific literacy; sensitization	Inferences; Talk; Summaries

Source: Prepared by the authors

4.2 DISCUSSION

The findings reveal a movement of resignification of the students' conceptions about the restinga. The initial vision, centered on the immediate use of space and the desirability of the boardwalk, confirms the social invisibility historically associated with restingas and documented in the literature on coastal ecology and conservation (MAGNAGO; MARTINS; PEREIRA, 2011; PEIXOTO; PEREIRA, 2006; RODRIGUES; LIMA, 2020). By anchoring teaching in the territory, the experience shifted the focus from an abstract content to a real object of investigation.

The fieldwork operated as cognitive and affective mediation: seeing, measuring and recording activated processes of signification that the exclusively expository class would hardly produce. This passage dialogues with the idea of scientific literacy as the ability to read the world through science, articulating observation, explanation and taking a position (CHASSOT, 2000). It also materializes problematization as a didactic principle, articulating content and reality (DELIZOICOV; ANGOTTI; PERNAMBUCO, 2011).

Critical Environmental Education proved to be decisive in interpreting degradation not as a "lack of individual care", but as a result of political-economic options in the occupation of the coast, with unequal effects on people and ecosystems (GUIMARÃES, 2004; LOUREIRO, 2012; LAYRARGUES; LIMA, 2011). This epistemic displacement appeared in the speeches and proposals of the groups, which began to relate impacts to local urban and tourist dynamics, pointing to collective responsibility.

PBL, resignified, functioned as an organization of the path, avoiding the risk of "task for task's sake" (BENDER, 2014). The cycle problematize–investigate–systematize–prototyping–socialize, enhanced by digital technologies (MORAN, 2018), favored protagonism and authorship: the students used Google Lens and Google Earth as instruments to read the territory, connecting empirical data to interpretation. Thus, the teaching role shifted to qualified mediation, ensuring conceptual rigor and security in the field.

The elaboration of prototypes of socio-environmental startups operated as a pedagogical language to transform evidence into intervention proposals. By being treated as educational artifacts — and not as a marketing essay — such proposals brought the school closer to contemporary repertoires of innovation without abandoning criticism (DORNELAS, 2018; RIES, 2012; SEBRAE, 2017). This strategy helps to tension the discourse of "efficient sustainability" by placing socio-environmental responsibility and territorial relevance at the center, in convergence with the critical macro-trend (LAYRARGUES; LIMA, 2011).

From the point of view of the curriculum, the results corroborate the guidelines of the BNCC and the Espírito Santo Curriculum regarding contextualization and investigative competencies (BRASIL, 2018; SEDU/ES, 2020). Experience shows that it is possible to mobilize ecology content (adaptations, succession, coastal dynamics) in authentic situations, producing meaningful and socially relevant learning.

In summary, the results indicate that:

- territory as living content contributes to overcoming the fragmentation of science teaching;
- critical EE broadens the interpretative horizon and fosters participation;
- PBL, when critically articulated, favors investigation and authorship;
- The socio-environmental prototypes work as a bridge between diagnosis and educational action, strengthening citizenship training.

Implications for teaching practice: plan investigative paths that include the field, digital tools, public systematization and educational products connected to the territory; to treat the language of innovation in a pedagogical way, maintaining the ethical-political horizon of critical Environmental Education.

5 CONCLUSION

This study analyzed how critical Environmental Education, in dialogue with Project-Based Learning and with the pedagogical language of socio-environmental entrepreneurship, can contribute to the valorization of the restinga and to the scientific and citizenship training of high school students. The path started from a diagnosis of ignorance and utilitarian views on the restinga, advanced through field investigation, systematization with the support of digital tools and socialization of results in educational products.

The four specific objectives were achieved. (i) The initial conceptions of the students were clearly identified, revealing the invisibility of the ecosystem and understanding reduced to practical functions. (ii) Critical Environmental Education guided the reading of the territory, favoring the understanding that the degradation of the studied stretch results from social and economic choices, and not only from individual behaviors. (iii) PBL, resignified as a situated research strategy, structured the path in problematization, field, analysis, prototyping and public feedback. (iv) The final products of the groups showed conceptual learning and

commitment to the local reality, through prototypes of socio-environmental startups conceived as pedagogical artifacts.

The results indicate consistent evidence of scientific literacy: the students began to relate empirical observations with ecological explanations, recognized the interdependence between flora, fauna and geomorphology, and used maps and coordinates to understand the spatial cut-out investigated. There was also socio-environmental awareness, with recognition of anthropogenic impacts and formulation of contextualized proposals for the valorization and conservation of the restinga. The use of Google Earth and Google Lens increased rigor and authorship in the analysis, without replacing teacher mediation or fieldwork.

Experience has shown that the language of innovation can be incorporated into a pedagogical key, without subordinating the educational process to market purposes. The prototypes worked as a bridge between diagnosis and educational action, reinforcing the centrality of the territory as living content and the school as a space for participation and collective accountability.

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