Chapter 8
A Problem-Based Learning Approach to Environmental Education Through a Field Trip and a Science Centre Visit

Manuella Villar Amado

Abstract The development of science and technology currently experienced by society has brought a degree of quality of life that humanity has never experienced before, but it has also created environmental problems that represent real challenges for today and the future. In this period known as the Anthropocene, teachers of basic education face the challenging task of preparing individuals for a world that is in constant transformation. In this context, it is necessary to establish teaching and learning strategies that will enable individuals to effectively solve existing problems, to make rational decisions, and to fully participate in a democratic society. Accordingly, this study presents an Intervention Program (IP) for scientific literacy, based upon and validated as a teaching strategy, centred on the Problem-Based Learning methodology (PBL), and applied to two different contexts of non-formal education, a field trip and a Science Centre visit. The research aims to directly contribute to teacher training, which in turn will produce long term effects on elementary school students, thereby contributing to sustainability. It is a qualitative study with 15 students in non-formal education, as part of a curricular unit from a professional master's degree in Science and Mathematics Teaching, which is taught in a federal institution in south-east Brazil. A methodological triangulation was applied with different instruments and data collection techniques, namely: logbook, questionnaires, focus groups, monitoring reports, PBL record, and student production (Teacher Guide and Sustainability Game). The development of the IP involved two scenarios of the PBL methodology and the construction and validation of scenarios with peers. The results led to the conclusion that, when applied to non-formal education spaces, PBL enhances distinctive features of teacher training (such as a privileged space for reflecting on education, its complexity, and the possibilities of transdisciplinary teaching practices), in addition to favouring the acquisition of knowledge that will promote attitudes concerned with sustainable development.

M. V. Amado (✉)
Programa de Pós-graduação em Educação em Ciências e Matemática (Educimat), Instituto Federal do Espírito Santo (IFES), Campus Vila Velha, Avenida Ministro Salgado Filho, 1000, Soteco, Vila Velha, Espírito Santo 29106-010, Brazil
e-mail: manuella@ifes.edu.br

C. Vasconcelos and C. S. C. Calheiros (eds.), *Enhancing Environmental Education Through Nature-Based Solutions*, Integrated Science 4,
https://doi.org/10.1007/978-3-030-91843-9_8

Keywords Environmental education · Anthropocene · Sustainability · Problem-based learning methodology

> Humanity needs more open minds, more sensitive listening, people who are responsible and committed to transforming themselves and the world!
>
> (Edgar Morin)

Introduction

Today we are living in the midst of an advancing socio-environmental crisis on a planetary scale, with serious ecological and socio-economic implications, migration and poverty, social inequalities, unemployment, environmental exploitation, and degradation and resource extraction. The term "Anthropocene" has been used to better describe the present epoch, in which the human species (Homo sapiens) has generated impacts on nature equivalent to a geological force capable of modifying the planet's biophysical parameters [1].

In the Anthropocene, the exploitation of environmental resources has caused worldwide degradation of forests, especially in tropical countries [2]. Brazil contains 22% of the planet's and 58% of South America's humid tropical forests [3]. However, deforestation rates here are also among the highest in the world [4]. This a period of endless crises due to globalization, westernization, and unsustainable development.

Edgar Morin [5] is emphatic when he says, there are only two paths, the abyss or metamorphosis. The direction of this second path needs to be carefully planned out. Some researchers [6, 7] believe that educational institutions have great potential for generating multipliers for socio-environmental sustainability.

In this context, it is necessary to establish teaching and learning strategies that will enable individuals to effectively solve existing socio-environmental problems, to make rational decisions, and to fully participate in a democratic society. Accordingly, this research presents an Intervention Program (IP) for environmental education, based upon and validated as a teaching strategy, centred on the Problem-Based Learning methodology (PBL), and applied to two different contexts of non-formal education, a field trip and a Science Centre visit.

Field trips may stimulate the participants' curiosity, their sense of empathy for creatures, and responsibility and unity with nature, maximizing the acquisition of information about nature and, ultimately, changing their conceptions about the importance of environmental conservation [8–10].

Science Centres are a type of museum, which, in the twenty-first century, are coming to be understood as 'polyphonic spaces' concerned with 'planetary well-being' [11]. Therefore, in addition to focussing on traditional concerns, museology needs to keep abreast of debates in global challenges and sustainable development. The ICOM recently adopted sustainability as one of its priority areas.

Problem-based learning (PBL) is a collaborative and participatory student-centred approach to teaching and learning, based on group work and problem exploration

[12]. The main aim of using PBL for sustainability education is for students to investigate real life sustainability problems—which are inherently socio-environmental, open ended, and without a simple solution [12]. Through this process, students develop a greater understanding of the multifaceted nature of sustainability issues and develop interdisciplinary skills in sustainability, as well as a range of professional competencies [12]. This range of skills includes, but is not limited to, effective communication; ethical awareness; global citizenship; discussion and negotiation; listening and respecting others; team work; self- and group-reflection; inter-cultural understanding; systems thinking; creative thinking; and stakeholder engagement [12]. PBL originates from medical education, specifically from McMaster University in Ontario, Canada, where it was pioneered in the 1960s [12]. The application of PBL in elementary schools will not be successful without the seriousness of the teacher, as classes require careful planning [13].

The objective of this study was to contribute to the training of elementary school teachers in Brazil, promoting knowledge acquisition in attitudes towards environmental education, using PBL applied to a field trip and a Science Centre visit.

Methodology

Sample

This is a qualitative study with 15 students in non-formal education, as part of a 30-h curricular unit from a professional master's degree in Science and Mathematics Teaching, which is taught in a federal institution in south-east Brazil. The research subjects were teachers with the following higher-level education: Biology (6), Chemistry (2), Physics (1), Geography (1), Mathematics (1), Social Sciences (1), Pedagogy (1), Civil Engineering (1), and Library Science (1). Most (10) graduated from a public higher education institution. They had an average of 13 years' experience as teachers. The gender distribution was as follows: 10 female students with an average age of 40 years old and 5 male students with an average age of 38.

PBL Process

As a teaching and learning strategy, PBL integrates a set of steps that allow the teacher to mediate the process. There are some proposals for the operationalization of PBL in the scientific literature, although the structuring and terminology used in describing such proposals are not consensual. The proposals presented by three authors for planning the PBL strategy are outlined below.

Almeida [14] mentions five stages of PBL: (i) identification of the problem (reading a statement, presenting a case or exposing a situation); (ii) problem analysis; (iii) synthesis of explanations, setting of objectives, decision making; (iv) systematization of the solutions found and application to real contexts; and (v) continuous assessment by students and teachers.

Trindade [15] suggests three steps for planning the teaching and learning strategy: (i) selection of the core notion to be addressed; (ii) formalization of the problem situation; and (iii) elaboration of a framework of activities to be carried out and resources to be used.

Delisle [16] presents the following PBL plan: (i) select content and competences; (ii) inventory available resources; (iii) write the problem statement; (iv) choose a motivating activity; (v) develop a focused question (end product); and (vi) define an evaluative strategy.

In this study we opted to use a plan based on the PBL stages presented by Vasconcelos and Almeida [17]. The choice of the Cycle Process is justified, essentially, for two reasons. Firstly, among the proposals found in the literature, the work of Vasconcelos and Almeida [17] is configured as one of the most exhaustive in strategy presentation. Secondly, the work of these authors includes several practical examples of strategic planning in the classroom at different levels of basic education, an aspect that appeared to facilitate its development. These authors adapted the structure into mandatory phases initially created by Lambros [18], which involves the heuristic steps shown in Fig. 8.1.

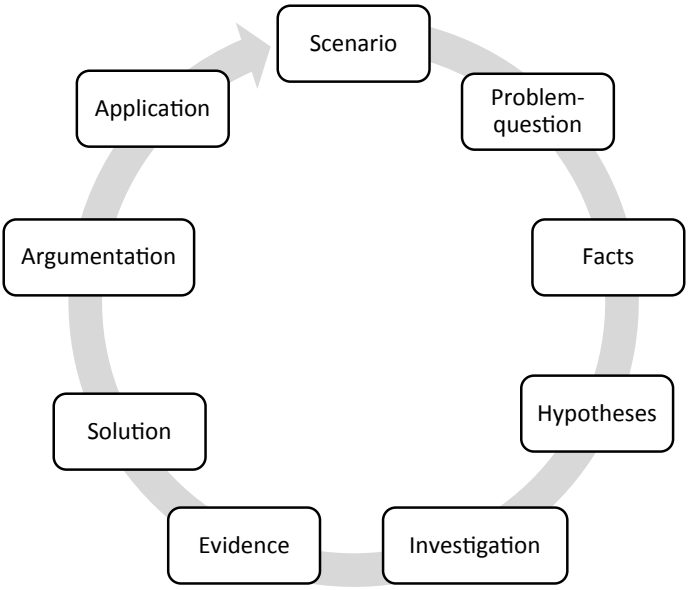

Fig. 8.1 PBL cycle process (adapted from Vasconcelos and Almeida (2012) (p.2))

Thus, the two scenarios (Scenario 1 and Scenario 2) built in this work followed the PBL plan of Vasconcelos and Almeida [17] and were based on the following structure:

(1) Title—name given to the problematic scenario.
(2) Curricular contextualization—indication of the level of education.
(3) Estimated time—time needed to carry out the proposed work.
(4) Prerequisites—correspond to the knowledge learned in previous years and that will help in the questioning and planning of the research activity to be developed.
(5) Objectives—related to knowledge and ability that students are expected to achieve with the development of research.
(6) Concepts – they are disseminated in school manuals or subject menus. They must be implicit to the selected theme and to the objectives to be achieved.
(7) Scenario—refers to problematic contextualization and can be presented in several ways: texts, news, photographs, or dialogues.
(8) Problem-questions—the planning of this item involves questions raised by the teacher, who tries to foresee the possible questions that will be raised by the students. During the intervention, it is at this stage that the students receive the PBL monitoring form to highlight the facts and raise their questions.
(9) Final product—is the expected product as a result of the research work.
(10) Data Sources—are consultation elements for students to find evidence to answer the problem-questions and have more information to contribute when communicating the proposed solutions to the class.
(11) Disciplinary articulation—indicate the connections of concepts between units of the same discipline or between different disciplinary areas.
(12) Presentation cycle—presents the sequence of activities that will be developed
(13) Application—allows you to assess the knowledge learned for applications involving critical thinking, scientific reasoning, and argumentation skills.

The Intervention Program (IP) consisted of classes and activities developed in two scenarios, Scenario 1 with a Science Centre visit and Scenario 2 with a field trip. After participating in the two scenarios, the students gathered into groups and planned a PBL scenario to be applied to a field trip or a visit to a Science Centre with elementary school students. On the last day of class, the groups presented the scenario and validated it through a questionnaire on the PBL plan of the other group (Fig. 8.2).

PBL Scenario 1—Science Centre Visit

Scenario 1 aimed to work on the definitions of non-formal, formal, and informal education; explore the concepts of museums and Science Centres, knowing the environments of museums and Science Centres; know the history of museums in Brazil; and create a work proposal for a Science Centre visit with the socio-environmental

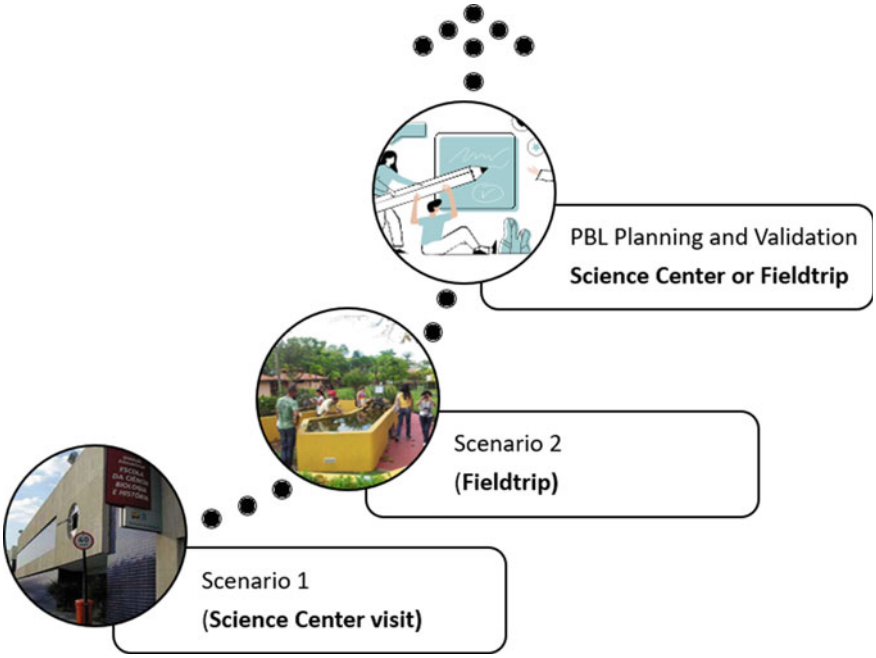

Fig. 8.2 Intervention Program (IP)

perspective of environmental education. Scenario 1 was structured in the sequence presented in Table 8.1.

The activities began with the presentation of the discipline's program and the research objectives. The first activity was a dialogic expository class where formal, non-formal, and informal education concepts were discussed. In the second activity,

Table 8.1 Scenario 1 presentation cycle

Class number (h)	Activity
2	– IP presentation – Research objectives presentation
2	– Concepts of formal, informal, and non-formal education presentations
4	– Science Centre visit: Escola de Ciências, Biologia, e História
2	– Reading a scenario – Online Museums visit in the computer lab – Formation of groups and filling out the PBL monitoring form
2	– Group dynamics: The web of life versus the web of knowledge – Reading and discussion of questions and answers – Concept reinforcement – Product presentations: The teacher's guide for the Science Centre 'Escola de Ciências, Biologia, e História'

Fig. 8.3 Science Centre visit: Escola de Ciências, Biologia, e História (School of Science, Biology, and History)

students visited the Escola de Ciências, Biologia, e História (School of Science, Biology, and History) (Fig. 8.3) located in the municipality of Vitória, in the state of Espírito Santo, Brazil. This Science Centre aims to democratize science and enable the population's access to knowledge on the ecosystems and historical heritage of Espírito Santo in a playful and interactive way. Its main mission is to express local culture and identity by discussing natural and cultural aspects of Ilha de Vitória (Vitória Island). There is an emphasis on the construction of the island's geographic space and also on the deterioration of local ecosystems along its historical path, in line with the construction of the country's history. The building where the Science Centre is located contains two floors. The first floor consists of an auditorium used to receive visitors. In this place, the students of the discipline had a lecture about the centre. On the second floor there are models of the regional historical heritage; archaeological artefacts that prove the existence of prehistoric populations in the region and elements of local identity; and a mockup of Vitória. Thus, it is evident that the Escola de Ciências, Biologia, e História has interdisciplinary characteristics involving knowledge that can contribute to environmental education and cultural recovery.

In the class after the visit, the students read the text of the problematic scenario about the space visited in the previous class, which also required virtual visits to online interactive museums, carried out in the computer lab. Soon after, they formed 3 groups of 5 students. The teacher started the next class with a dynamic to reflect on

Fig. 8.4 Group dynamics: the web of life versus the web of knowledge

the group work, called Ecological Web, comparing an ecosystem web of the Atlantic Forest with the web of knowledge. Students were asked to stand in a circle and name a biotic or abiotic factor in the Atlantic Forest ecosystem and throwing the ribbon to another person, who needed to name another biotic or abiotic factor related to the aforementioned factor, explaining the relationship. After the formation of the web, the teacher began to interfere by simulating a hunter and then the pollution of water resources. When they observed that every factor influences the others, the teacher asked them to reflect on group work, on the importance of having a web of knowledge, and on the interdependence of these elements to perform teamwork well (Fig. 8.4).

PBL Scenario 2—Field Trip

Scenario 2 aimed to work on the concept of environmental education. The activities developed are summarized in Table 8.2.

In the first class, the students were invited to play the Brazilian equivalent of the Go Green edition of Monopoly that exists commercially in Brazil, namely *Banco Imobiliario Sustentavel*. This game is the sustainable version of Monopoly with great emphasis on sustainability issues, in which the materials that make up the game like the pieces, which come from sugar cane, are highlighted. The game is based on the purchase of sugarcane producing regions and forest reserves with carbon credits (Fig. 8.5). After the playful activity, the teacher read Scenario 2: The *Banco Imobiliario Sustentavel* Game. Then the students got together in two groups to compare the two commercial games: *Banco Imobiliario Sustentavel* and Monopoly.

Table 8.2 Scenario 2 presentation cycle

Class number (h)	Activity
4	– *Banco Imobiliario Sustentavel* Game application – Scenario Reading: *Banco Imobiliario Sustentavel* – Collective elaboration of the problem questions on the board – Formation of groups
4	– Field trip: Vale Botanical Park
4	– Reading and discussion of answers – Preparation of the final product: a board game with the principles of environmental education
4	– Application and validation of produced games
2	– PBL planning by groups
2	– PBL plan presentations and validations

Fig. 8.5 *Banco Imobiliario Sustentavel* application

The next class was a fieldtrip to the Vale Botanical Park in Vitória (Fig. 8.6), which has 33 ha and is the green belt of the Vale mining company. It is considered a space for leisure, environmental education, and, above all, a conservation unit in the Atlantic Forest, one of the most important forests in the country. The park is home to more than 140 species of trees, such as pau-brasil, jacaranda, and Ipe, in addition to wild animals such as possums, marmosets, and several species of bird that can be seen on five ecological trails available to visitors. The park also has an orchidarium, a sensory garden, exhibition areas, and a library. The park offers buses to visit the interior of Vale's industrial complex.

Fig. 8.6 Fieldtrip: Vale Botanical Park

In the field class, students had the autonomy to respond to a field guide during the following activities: in the open part of the park, observe and get to know the selective collection carried out on site; in the sensory garden, observe and perceive the characteristics of the plants related to the 5 senses; on the trail, understand the process of environmental restoration and habitat fragmentation in the Atlantic Forest; and in the industrial area, know the main stages of the pelleting process.

After the visit, the students gathered in the classroom to read and debate the answers on the PBL monitoring sheet. The teacher ended the debate with a dialogued expository class on the different concepts of environmental education. At the end of the class, the students gathered in groups again to prepare the final product, which was a board game with social-environmental issues. In the last class, the students delivered the games and each group "played" the game made by the other group.

Instrument

For data collection, methodological triangulation was applied using different instruments and techniques (Table 8.3). The teacher-researcher, through the classroom diary, made an assessment of the process in the relevant aspects of student motivation, participation, group functioning, and difficulties and limitations with the

Table 8.3 Instruments and data collection techniques

Instrument	Data collection technique	Data analysis technique	Objective
Classroom diary	Observation	Content analysis	Describe the intervention program
Scenario products (Scenarios 1 and 2)	Inquiry	Content analysis	Assessment of Scenario 1 and Scenario 2 products for the three pillars of sustainability (economic, environmental and social)
Focus group (Scenario 2)	Inquiry	Speech analysis	Evaluation of games produced as the final product of Scenario
Questionnaire	Inquiry	Content analysis	Investigate PBL plan validation

adopted methodologies. To assess the contributions of the PBL methodology to environmental education, the final product of Scenario 1, the Teacher's Guide made by the students, was evaluated for the presence of the three pillars of sustainability (economic, environmental, and social) [19]. A focus group was formed during class to evaluate the final product of Scenario 2, which was a board game with the theme of sustainability. The focus group is a non-directive group discussion technique, which brings together people with certain common characteristics or experience to discuss a topic or area of interest. Focusing on a certain subject, the discussion does not seek consensus, but raises different opinions, attitudes, thoughts, and feelings, expressed verbally or otherwise, in a relatively short time [20].

Because the sample size was small ($n = 15$), descriptive statistics were used to verify the frequency of questionnaire responses. Scenario products were subjected to content analysis [21] by identifying units of analysis, in this case, phrases that reveal certain ideas in categories and subcategories [22].

We also sought to present the ideas expressed by the students, through the inclusion of full or partial lines, chosen according to the researcher's assessment of their relevance. The focus group was analysed to understand the real discourse through the central ideas and anchorages, using the discourse analysis technique [23]. Thus, the study sought to carry out a combination of analyses, using methodological triangulation, to interpret the results obtained from the intervention program.

Results and Discussion

Scenario 1 Analysis: Teacher's Guide

The students produced a "Teacher's Guide" for use in the space visited in Scenario 1 (Escola de Ciências, Biologia, e História), which was analysed from the perspective of interdisciplinarity and environmental education. Three guides were produced and analysed. A content analysis was carried out on the guides in order to find evidence of the three pillars of sustainability. These perspectives were also classified into subcategories, according to what was found in the students' scripts (Table 8.4).

The results point to an integration of the three pillars of sustainability content in all the guides developed by the students. As the mission of the Science Centre is to express the local culture and identity from the natural and cultural aspects of Ilha de Vitória, we believe that the very design of its exhibitions helped students in the construction of interdisciplinarity guides focused on the perspective of socio-environmental issues.

Scenario 2 Analysis: Game for Environmental Education

The games made by the students of the discipline, as the final product of Scenario 2, were also analysed for the presence of the three pillars of sustainability, in addition to analysing the game in terms of pedagogical aspects.

Group 1 made a board game entitled "Sustainability" (Fig. 8.7) containing a board, a dice, five pieces of animals from the Brazilian forest (armadillo, frog, snake, macaw, and toucan), and several cards. The objective of the game is to follow a path in the state of Espírito Santo on a trail made with figures representing companies and aspects of culture and the environment in that state of Brazil.

Group 2's game (Fig. 8.7) was entitled "Sustainable Attitude" and was made up of a board, a dice, four carts, several cards, several paper CO_2 molecules, and several paper trees. The objective of the game is to contribute to the environment by removing as many CO_2 molecules from the atmosphere as possible, which happens with every sustainable attitude of the player, who contributes by planting trees. For every six CO_2 molecules removed from the atmosphere, the player earns the right to plant a tree. The player who plants the most trees wins the game.

The games were evaluated though group debate, in which all the students were able to express and debate their opinions. Table 8.5 was used, with Yes and No, to categorize the results of the evaluation of the games regarding the level of agreement of opinion among the participants. Thus, Yes shows that everyone agreed with a positive answer, the No shows that everyone agreed with a negative answer, and the Yes/No shows that there was an impasse and a disagreement between the participants.

As for the didactic performance, the two games were evaluated as a pedagogical practice that contributes to the teaching and learning of scientific concepts, without

Table 8.4 Three pillars of sustainability analysis

Category	Subcategories analysed in the guides	G1	G2	G3
Economic	– Presents the place as fun and educational – Describes the conditions of the physical structure and location of the place – Presents the mission of the place in dealing with the historical heritage of ES – Presents the historical heritage of ES – Presents a tour guide that values the tourist centre of Vitória – Presents the model of the city of Vitória	X X X X X	X X X X X	X X X X
Environmental	– Presents the exhibition of Restinha, Mangrove, and Atlantic Forest ecosystems – Presents the site's mission to disseminate knowledge on the ecosystems present in ES – Presents citizenship training from an environmental education perspective – Presents a visit itinerary that focuses on the characteristics of the mangrove ecosystem and the implications of the capture and commercialization of the Uçá crab – Presents a visit itinerary that deals with the concept of ecosystems and the characteristics of ecosystems present in ES – Presents the possibility of working on the degradation of ecosystems due to population growth – Presents the landfill areas and the green areas in the Vitória model	X X X X X X X	X X X X	X X X X
Social	– Presents the mission of the place in expressing the local culture and identity – Presents cultural rescue and social inclusion – Describes the diversity of possible pedagogical scripts for educational action – Presents the archaeological sites and the possibilities of working on prehistory and its relationship with the present – Presents the space's creation story – Presents the integration of nature and culture to talk about the identity of the city of Vitória – Presents the possibilities of also working with knowledge such as art and/or literature	X X X X	X X X X X X X	X X X X X X
Interdisciplinarity	– Presents interdisciplinarity	X	X	X
Three pillars	– Presents articulation between the three pillars of sustainability	X	X	X

(a) Group 1 Game: "Sustainability" (b) Group 2 Game: "Sustainable Attitude"

Fig. 8.7 The games made by the students of the discipline, as the final product of Scenario 2

Table 8.5 Focus group work inquiry to validate the games produced by students

Game evaluation	G1	G2
Didactic performance	Y	Y/N
(1) Are the rules clear? Is it easy to understand and play?	N	N
(2) Are there any conceptual errors?	Y	Y
(3) Does the game contribute to teaching and learning scientific concepts?		
Sustainability assumption	Y	Y
(4) Does it encourage critical thinking by the students?	Y	Y/N
(5) Does it stimulate reflections on the social and environmental problems generated by capital?	Y	Y/N
(6) Can the game articulate the 3 pillars of sustainability - Economic, Social, and Environmental?	Y	N
(7) Does the game have social and environmental responsibilities for various actors (individual, collective, public policies)?		

Subtitle: Y = Yes; N = No; Y/N = no consensus

presenting conceptual errors. The Group 1 game rules are based on those of a regular board game, so they are relatively clear and the game starts easily. The rules of the Group 2 game, however, are not so clear, and require careful reading of the game manual. Despite being more complex in terms of rules, the Group 2 game proved to be much more creative and innovative.

As for the assumptions of socio-environmental issues, we observed that the two games meet the expectations of stimulating the student's critical thinking. However, the Group 2 game did not fully achieve the objective of stimulating social reflection and therefore one of the pillars of environmental education was not well incorporated into the rules of the game. This is because the Group 2 game does not have several social actors with socio-environmental responsibilities, with the expected changes being focused only on the individual behaviour of students.

According to Edgar Morin [5] the vision of the whole and the parts needs to be worked on in order to achieve a glimpse of the complexity of reality. Environmental education needs to be focused on the problematization experienced and also on the

recognition of nature's relationships with social groups and the "place" occupied by these in society. This reflection seeks new syntheses that indicate new democratic, sustainable, and fair paths for all.

PBL Plan Validation

At the end of the intervention program, the students planned a PBL scenario to be applied in a non-formal education space. **PBL 1** was "Hair-raising!", to be applied in the Escola da Ciência-Física (School of Science and Physics) Science Centre, located in Vitória, ES, Brazil; and **PBL 2** was "Garbage: An everyday problem", to be carried out as a field class at the "Marca Ambiental" landfill, located in Cariacia, ES, Brazil.

The "Hair-raising!" scenario was developed for 9th grade elementary school students and had the following objectives: make students observe the concepts of types of electrification using the Van de Graff generator; explain the small shocks we take in everyday life through electrostatics; differentiate conductors from electrical insulators; and understand how a material can be electrified. The final product proposed was to develop experimental activities that demonstrate the types of static electrification (contact, induction, and friction) and relate them to real everyday situations.

At the end of the "Hair-raising!" presentation, the group that was watching commented that the scenario lacked an interdisciplinary and socio-environmental perspective, as the focus was on the conceptual contents of the discipline of physics. There were even suggestions for working with lightning and thunder from the perspective of damage to the environment, the dangers of a person being hit, and the precautions that should be taken.

Students filled out a Scenario Plan Validation Questionnaire for "Hair-raising!" and the results are shown in Table 8.6. During the validation of the plan, it was evident that some adjustments were needed to contemplate the interdisciplinarity and socio-environmental issues relevant to environmental education, as shown in the speeches of the subjects (S) below about using this scenario in their classes.

S1: "Yes. However, I would try to promote greater interaction between disciplines."
S2: "Yes. In an articulated way, not focusing only on conceptual content."
S4: "The theme could have been addressed in a more creative and interdisciplinary way."
S5: "I couldn't see other subjects in the PBL presentation, I only noticed physics and biology."
S6: "The topic has the potential to address the socio-environmental issue, but it was not focused on."

The "Garbage: an everyday problem" scenario was developed for 1st year high school students and had the following objectives: to relate the impact caused on the

Table 8.6 PBL planning validation

PBL planning	PBL 1 "Hair-raising!"					PBL 2 "Garbage: an everyday problem"				
Category	1	2	3	4	5	1	2	3	4	5
Theme (contextualization)	0	0	2	3	3	0	0	0	1	4
Curriculum contextualization	0	0	0	2	6	0	0	0	0	5
Time	0	0	0	3	5	0	0	0	3	2
Prerequisites	0	0	2	0	6	0	0	0	2	3
Specific objectives	0	0	2	2	4	0	0	0	3	2
Disciplinary articulation	0	2	4	2	0	0	0	0	1	4
Concepts	0	0	1	4	3	0	0	1	1	3
Scenario	0	0	1	5	1	0	0	0	1	4
Sustainability perspective	0	1	3	3	1	0	0	0	2	3
Articulation with formal and non-formal education	0	0	0	1	7	0	0	0	0	5
Survey of problem-questions	0	0	0	1	7	0	0	1	1	3
Final product	0	0	2	2	4	0	0	0	2	3
Data source	0	0	1	2	4	0	1	0	1	3
Tutorial cycle steps	0	1	1	5	1	0	0	0	2	3
Application	0	0	3	3	2	0	0	0	1	3
Evaluation proposal	0	0	2	5	1	0	0	1	3	1
Originality of the PBL proposal	0	0	4	3	2	0	0	3	1	1
Clarity and intelligibility of the proposal	0	0	2	4	2	0	0	0	2	3

environment by inappropriate waste disposal; understand that the waste produced can be reused; relate the issue of waste production reduction and consumption control; relate soap production to chemical transformation processes; and raise awareness in the school community about the production, disposal, and reuse of waste. The disciplinary articulations involved Biology, Chemistry, Sociology, Physics, and Portuguese Language. The final product was the production of documentary videos on the consumption and reuse of waste. At the end of the scenario presentation of "Garbage: an everyday problem", all the students who were watching expressed satisfaction with the proposal. This plan works the conceptual contents within an interdisciplinary perspective and explores the relevant socio-environmental issues of environmental education, as pointed out in the speeches of the subjects (S) below, when asked if they would apply this plan in their educational context.

S7: "Yes. Throughout the year in an interdisciplinary way involving the environment and health."
S8: "Yes. I could use it to talk about the waste produced by the mining sector."

S9: "Yes. Because it is relevant and enhances socio-environmental issues, allowing for articulation with other disciplines."
S10: "Yes. Because the proposal presented is relevant and constituted in a cohesive and conscious way."
S11: "Yes. Due to coherent planning and relevant themes."
S12: "Yes. The work made the great concern with socio-environmental issues very clear at all times."

As for the negative aspects, only the assessment that focused on conceptual knowledge was mentioned.

Thus, in the analysis of the two PBL scenarios elaborated by the research subjects, the plan of the "Garbage: an everyday problem" scenario group managed to achieve all the goals. However, even the IP did not guarantee the break with the paradigmatic conceptions of traditional teaching in the plan of the "Hair-raising!" scenario. We believe the fact that the chosen science centre, the Escola da Ciência-Física, still has characteristics of disciplinary fragmentation, contributed to this result.

Conclusion

We found that applying the PBL methodology to Scenario 1 and Scenario 2 enhances the development of skills such as critical thinking, argumentation, writing, communication skills, teamwork, and the search for solutions to problems and promotes the collective construction of knowledge. It was evident that the methodology was well accepted to be applied in different degrees of academic training, be it elementary, secondary, or higher education.

The results also lead to the conclusion that, when applied to spaces of non-formal education like Science Centres and field trips, PBL enhances distinctive features of teacher training (such as a privileged space for reflecting on education, its complexity, and the possibilities of interdisciplinary teaching practices), in addition to favouring the acquisition of knowledge that will promote attitudes concerned with sustainable education, which are much needed features in this new epoch, the Anthropocene.

References

1. Léna P, Issberner L (2018) Desafios para o Brasil em Tempos de Antropoceno. In: Peter MH (eds) Economia do meio ambiente: Teoria e prática. Elsevier, Rio de Janeiro, pp 205–230
2. Choksi P (2020) Examining patterns and impacts of forest resource extraction and forest degradation in tropical dry forests. In: Bhadouria R, Tripathi S, Srivastava P, Singh P (eds) Handbook of research on the conservation and restoration of tropical dry forests. IGI Global, pp 171–192. https://doi.org/10.4018/978-1-7998-0014-9.ch009
3. Freitas JS, Mathis A, Caldas MM, Homma AKO, Farias Filho MC, Rivas AAF, Santos, KM (2021) Socio-environmental success or failure of extractive reserves in the Amazon? Res Soc Dev 10(5):1–18. https://doi.org/10.33448/rsd-v10i5.14631

4. Stropp J, Umbelino B, Correia RA, Campos-Silva, J V, Ladle, RJ, Malhado, ACM (2020) The ghosts of forestspast and future: deforestation and botanical sampling in the Brazilian Amazon. Nordic Soc Oikos 43(1):1–11. https://doi.org/10.1111/ecog.05026
5. Morin E (2013) A via: para o futuro da humanidade. Bertrand Brasil, Rio de Janeiro
6. Jacobi PR, Toledo RF, Grandisole E (2016) Education, sustainability and social leaming. Braz J Sci Technol 3(3):1–8. https://doi.org/10.1186/s40552-016-0019-2
7. Rodrigues J, Loureiro CF (2017) Pela formação integral de educadores: as dimensões reflexivas, crítica e ambiental. Educação em Foco 22(1):1–25. https://doi.org/10.22195/2447-524620172219885
8. Dienno C, Hilton S (2005) High school students' knowledge, attitudes, and levels of enjoyment of an environmental education unit on nonnative plants. J Environ Educ Phila 37(1):13–25. https://doi.org/10.3200/JOEE.37.1.13-26
9. Farmer J, knapp D, Benton GM, (2007) An elementary environmental education field trip: long term effects on ecological/environmental knowledge and attitude development. J Environ Educ Phila 3(3):33–42. https://doi.org/10.3200/JOEE.38.3.33-42
10. Knapp D, Poff R (2001) A qualitative analysis of the immediate and short-term impact of an environmental interpretative program. Environ Educ Res Abingdon 7(1):55–65. https://doi.org/10.1080/13504620124393
11. ICOM website (2021) Museum Definition. https://icom.museum/en/activities/standards-guidelines/museum-definition. Accessed 29 June 2021
12. Bessant, SB, Patrick B, Zoe RC, Tomkinson B, Tomkinson R, Mark Ormerod R, Boast R (2013) Problem-based learning: a case study of sustainability education. Technical report. https://www.researchgate.net/publication/264082416_Problem-Based_Learning_A_Case_Study_of_Sustainability_Education. Accessed 29 June 2021
13. Aldabbus S (2018) Project-based learning: implementation & challenges. Int J Educ Learn Dev 6(3):71–79. https://www.researchgate.net/publication/328368222. Accessed 29 June 2021
14. Almeida ACF (2002) A aprendizagem baseada em problemas: Uma solução para problemas de aprendizagem? O que dizem os alunos. Revista Portuguesa de Pedagogia 36 47–60. https://impactum-journals.uc.pt/rppedagogia/index. Accessed 10 Jan 2014
15. Trindade R (2002) Experiências Educativas e Situações de Aprendizagem (Colecção Guias Práticos). Edições Asa, Porto
16. Delisle R (2000) Como realizar a aprendizagem baseada em problemas (Colecção Cadernos do CRIAP). Edições Asa, Porto
17. Vasconcelos C, Almeida A (2012) Aprendizagem Baseada na Resolução de Problemas: Propostas de trabalho para Ciências Naturais, Biologia e Geologia. Porto Editora, Porto
18. Lambros A (2002) Problem-basead learning in K-8 classroom. Corwin Press, Thousand Oaks
19. Purvis B, Mao Y, Robinson D (2018) Three pillars of sustainability: in search of conceptual origins. Sustain Sci 14(1):681–695. https://doi.org/10.1007/s11625-018-0627-5
20. Placco, VMNS (2005) Um estudo de representações sociais de professores do Ensino Médio quanto à AIDS, às drogas, à violência e à prevenção: o trabalho com grupos focais. In Menin, MSS, Shimizu, AM Experiência e representação social: questões teóricas metodológicas. Casa do Psicólogo, São Paulo, pp 295–314
21. Bardin L (2004) Análise de conteúdo, 3ª. Edição, Edições 70, Lisboa
22. Cohen L, Manion L, Morrison K (2007) Research methods in education. Routledge, London
23. Lefevre F, Lefevre AMC (2012) Depoimentos e discursos: uma proposta de análise em pesquisa social. Líber Livro, Brasília