

# An ocean literacy intervention in elementary education: Exploring the society-nature relationship through the case of Guanabara Bay (Rio de Janeiro, Brazil)

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## ABSTRACT

The socio-environmental crisis—characterized by pollution, biodiversity loss, climate emergencies, and hunger—stems from a society-nature relationship driven by the exchange value of natural resources at the expense of human needs. Educational interventions play a vital role in elucidating the structural causes of environmental degradation. Ocean Literacy (OL) is a movement that seeks to “understand the influence of the oceans on humans and vice versa”, offering a historical perspective for examining the relationship between society and nature. This study implemented an OL intervention centered on Guanabara Bay (Rio de Janeiro, Brazil), engaging classes in situation of school retention in a public school in Niterói (Rio de Janeiro, Brazil). Activities included lectures, a mock trial, educational games, brainstorming sessions, and field trips. The results revealed that students initially lacked awareness of the Bay’s historical, economic, cultural, and social significance and showed limited interest in preservation efforts. However, after the intervention, students demonstrated an understanding that the Bay’s current state is the outcome of a historical process shaped by diverse social relations.

## 1. Introduction

The world is currently experiencing a rapidly intensifying socio-environmental crisis. Issues such as marine and ocean pollution, biodiversity loss, the climate emergency, and the spread of hunger are escalating at an alarming rate [46,56,71]. This crisis is intrinsically linked to the dichotomy between society and nature that defines modern existence [45] and was first theorized by René Descartes [22] which assigned a pragmatic role to knowledge, viewing nature as a resource and, therefore, establishing a form of anthropocentrism [43]. The subsequent consolidation of pragmatism and anthropocentrism came with the capitalist mode of production, particularly following the Industrial Revolution of the 19th century [7,27]. The rapid advancement of science and technology reflected modern society’s triumph of pragmatism, reducing nature to an entity to be controlled and exploited. An illustrative example of this estranged relationship is Guanabara Bay in Rio de Janeiro, Brazil which despite its historical, economic, cultural, social, and scientific significance, it is one of the most ecologically degraded ecosystems.

Overcoming the pragmatic and anthropocentric perspective that disconnects humans from their environment—a perspective exacerbated by the capitalist mode of production—has been pursued through various strategies, including education as a critical tool for addressing these issues [56,58]. Since the Stockholm Conference in 1972, Environmental Education (EE) has been a central approach to addressing environmental challenges [60] and in the context of Guanabara Bay, Coastal and Marine Environmental Education (EACM) has been employed as a framework for work and study [33,59,68]. Ocean Literacy (OL), which originated in the United States in 2004 and was introduced in Brazil in 2019 is a new strategy to tackle the ecological crisis in the ocean and has proven to be a vital tool in addressing educational challenges related to marine environments [62] but also to scientific understanding of marine problems in contemporaneity, sustainable resource management, public policy, and social participation.

Ocean Literacy is defined as a movement that seeks to promote “the understanding of the oceans’ influence on you and your influence on the ocean” [17] and was first established as an intervention in formal education defining seven principles that should be integrated into school

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curricula at the basic education level to enhance students' knowledge and provide them with the foundation to make informed decisions about the conservation and management of marine ecosystems [17,62]. However, soon the literature started to describe that intervening in formal education and by only the dimension of knowledge does not guarantee sustainable behaviour in relation to the ocean and its environments [51]. This was due the fact that society-ocean relationship is complex and mediated by many different dimensions. For example, Brennan et al. [14] proposed that beyond knowledge other five dimensions should be considered in OL interventions which are Awareness, Attitude, Communication, Behavior; and Activism. Furthermore, McKinley et al. [51] underlined the importance of social aspects related to society-nature relationship; therefore, they suggested the incorporation of another four dimensions in the framework of OL which were Emotional Connections, Access and Experience, Adaptive Capacity and Trust and Transparency. At this point OL movement extended to questions related to culture, society and economy searching a total well being of ocean-society interaction [72].

In this study, OL activities were developed and implemented with elementary school students from a public school in Niterói, Rio de Janeiro, Brazil, therefore, focusing the action on formal education from a perspective that favors the work through the ten dimensions of OL. The intervention aimed to reshape students' perspectives on the society-nature relationship using the environmental issues of Guanabara Bay as a case study. The research addressed the following questions: Are teaching activities that address the society-nature relationship able to give students a perspective beyond individualistic, utilitarian and pragmatic of management and use of natural resources? Can an OL intervention based on local problems favor student's comprehension of a historical nature of the society-nature relationship? How do students evaluate the intervention?

## 2. Materials and methods

### 2.1. Environment setting of Guanabara Bay

Covering a surface area of 384 km<sup>2</sup>, the Guanabara Bay is eutrophic [39], presenting problems such loss of biodiversity and habitat, fisheries collapse, silting, among other [16,26,29]. Thus, the challenges facing Guanabara Bay exemplify the broader societal relationship with nature, characterized by objectification and exploitation. This framework reinforces the perception of humanity as distinct from and superior to nature, perpetuating the ecological crisis we face today [1,32].

The degradation of the Bay began with the arrival of Europeans, whose exploitation of Brazil wood and other natural resources initiated the deforestation of the Atlantic Forest [26,69]. Colonization introduced an agricultural-export economy reliant on slave labor, resource extraction, and economic subordination to international capital. This development model negatively impacted local populations who depended on these resources for survival and caused lasting environmental harm [4, 69].

The most severe degradation of Guanabara Bay occurred in the 20th century, driven by urbanization under an industrial development model [3,26]. From the 1950s onward, rapid urban growth established the region as Brazil's second-largest industrial hub within the Guanabara Bay River Basin [13,20]. The industrial economic model exerted significant destructive pressure on natural resources, the material basis for societal production and reproduction [48]. Industrial waste dumping, landfills, soil misuse, and bottom sedimentation became prevalent problems within this bay, rooted in the region's unregulated industrialization and urban expansion [26,55].

### 2.2. Location and participants

The intervention was conducted at a public elementary school in Niterói, located in the metropolitan region of Rio de Janeiro. This school

was selected for three key reasons. First, its location in a low-income working-class neighborhood made it an ideal context for introducing Ocean Literacy (OL) to promote the collective organization and the appropriation of natural and cultural resources, fostering students' sense of belonging and citizenship. Second, the school's proximity to Guanabara Bay—the central focus of the intervention—allowed for direct engagement with the topic and its related activities. Finally, the school participates in the *Onda Cultural* educational project (website: <https://ondacultural.uff.br/>), a collaboration between researchers from Fluminense Federal University (Rio de Janeiro, Brazil) and public schools.

Three classes were chosen for the intervention all composed of students held back in grades below the expected level for their age (classes in situation of school retention). This selection offered an opportunity to use the proposed activities as a motivational tool while also enhancing the teaching-learning process, particularly in areas such as reading and writing skills.

### 2.3. Intervention structure

The intervention was designed based on the active-learning methodology, where students are actively and experientially engaged in tasks, while the teacher serves as a facilitator guiding their learning process [12,19]. All activities were framed within principles, concepts, and dimensions of Ocean Literacy [51,72]. A total of five activities were designed and conducted to build up gradually a perspective of society-nature relationship taking Guanabara Bay as a case study where this relationship could be apprehended by children from elementary education (Table 1).

The first step was to define student's previous knowledge, perceptions, attitudes and emotional connections with the Guanabara Bay, both at the level of environment and problems related with it (see Section 2.3.1. for specific procedures on this step). In doing so it was defined a framework of how to work in the next step which was a "Didactic game", that is what were the points to be stressed and vice-versa by the teachers and researchers during the playing. The main aims at this point were to mobilize the dimensions in some way linked to knowledge such as Awareness, Attitude, Behavior and Adaptive Capacity. Furthermore, information from images and texts were organized in a time line and the playing process was fully guided by discussions on rights and wrongs until the historical panel could emerge ready in front of the students (see Section 2.3.2). The development of this building of a historical perspective was to discuss the forces guiding this process what was done by a Mock Trial (see Section 2.3.3). History is a complex phenomenon defined by many different factors acting differently the way along, therefore, at this point it was necessary to reduce the complexities of social phenomena and their defining factors to those ones of higher interest to the desired perspective and objectives established for the intervention which were the unveiling of the society-nature relationship. In doing so we trusted that besides all the other mobilized dimensions we would be working Activism, Communication and Trust and Transparency with students.

Having defined the working framework, developed the historical perspective and practiced the discussion, it was time to settle and test what had been being built in a field trip where students could be presented to a real and concrete perspective of what they were working by different and complementary didactic strategies (see Section 2.3.4). Finally, the advances and limits of the intervention were evaluated based in the defined aims including the enjoyment of the students (or not) in the experience of have had participated in the proposed and executed educational intervention. That was done using questionnaires (pre-test and post-test) but also the personal observations of the researchers which despite being very subjective are invaluable sources of information in educational interventions (see Section 2.3.5).

#### 2.3.1. Brainstorming

The first step of the intervention was a pre-test and brainstorming

**Table 1**

Overview of the intervention activities implemented at the school, including application time, educational goals, and the Ocean Literacy principles, concepts, and dimensions addressed. For a complete list and definition of the OL principles and concepts see [72]. For a full description of OL dimensions, see [51].

| Activities                   | Pre-test Brainstorm                                   | Board Game                                                     | Mock Trial                                                                                                   | Field Trip                                                                | Post-test Evaluation                                      |
|------------------------------|-------------------------------------------------------|----------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------|-----------------------------------------------------------|
| <b>OBJECTIVES</b>            | Check students' familiarity with the subject          | Discuss the relationship between nature and society in history | Discuss ways of relating society and nature                                                                  | Observe social activities with the environment                            | Investigate the potential change in students' perspective |
| <b>Principles (Concepts)</b> | 6 (B, C, D)                                           | 1 (G)<br>5 (A, C)<br>6 (B, C, D, F)<br>7 (C)                   | 1 (G, H)<br>4 (C)<br>5 (A, C, D)<br>6 (A, B, C, D)<br>7 (F)                                                  | 1(H)<br>5 (D)<br>6 (B, C, D, G)                                           | 5 (A, E)<br>6 (A, B, D)                                   |
| <b>Dimensions</b>            | Knowledge; Awareness; Attitude; Emotional Connections | Knowledge; Awareness; Attitude; Behavior; Adaptive Capacity    | Knowledge; Awareness; Attitude; Behavior; Activism; Communication; Trust and Transparency; Adaptive Capacity | Knowledge; Awareness; Attitude; Behavior; Activism; Access and Experience | Knowledge; Awareness; Attitude                            |
| <b>Time</b>                  | 45                                                    | 45                                                             | 90                                                                                                           | 210                                                                       | 90                                                        |
| <b>Total Time</b>            | 480 min                                               |                                                                |                                                                                                              |                                                                           |                                                           |

- Principle 1 is defined as "Earth has one big ocean with many features", meanwhile its' concepts G and H relate to ocean connectivity with other bodies of water (lakes, rivers and streams) and to the fact that oceanic resources are limited, respectively.

- Principle 4 is defined as "The ocean makes Earth habitable", and its' C concept refers to the nutrients, oxygen, water and climate stability provided by the ocean.

- Principle 5 is defined as "The ocean supports a great diversity of life and ecosystems", and its' concepts A, C and D refer to marine biodiversity characteristics such as size, scale, and adaptations, while concept E regards the extensive range of marine ecosystems.

- Principle 6 is defined as "The ocean and humans are inextricably interconnected", with concepts A, B and C referring to the influence ocean has on society for supplying freshwater, food, medicines, minerals, and also inspiration. Concepts D and F refer to the ways society affect the ocean, through oceanic laws, pollution and coastal occupation, while concept G regards the shared responsibility for caring about the ocean.

- Principle 7 is defined as "The ocean is largely unexplored", with concept C referring to the drastic increase in the use of ocean resources in the last 50 years, while concept F refers to the interdisciplinary character of oceanic exploration.

session. The pre-test applied was interested in obtaining from student's personal data, knowledge on socioeconomic and biodiversity aspects and opinions on pollution and preservation all referring the Guanabara Bay (further information on pre-test is given in section on Evaluation). Additionally, a brainstorming session was carried out, which consists in a group dynamic where participants respond to a prompt by sharing their ideas on a given topic [2]. By doing so, this technique fosters group creativity in order to generate ideas, solutions and clarifications, and it has been used in different settings, including the educational realm [2]. In this version of the brainstorm, students wrote words on post-its that came to mind when prompted with the term "Guanabara Bay" (free association process). The collected words were digitized using the wordcloud.com software, which generates word clouds—graphic representations where terms appear in varying sizes based on frequency [5]. The resulting word cloud was then used as a starting point for a discussion, encouraging students to reflect on and analyze the associations with Guanabara Bay. This activity, although not in an organized way, gave to the researchers insights on students grasp with aspects of ocean-humans links (Principle 6 of Ocean Literacy) especially regarding perceived benefits (Concept 6-B), possible emotional links (Concept 6-C) and problems (Concept 6-D), all of them very useful in defining strategies for the next activity projected.

The referred concepts go beyond the dimension of knowledge having important connections with other Ocean Literacy dimensions such Awareness, Attitude and Emotional Connections [70], all of them complex structures elusive to objective measurements. However, some observable answers can be collected by verbal statements, body signals, manners and conduct [54,75]. Therefore a data collection on this activity was done by means of two instruments. First, the post-its were collected and subject to categorization following principles of content analysis [8] with a further simple statistical description (e.g., frequency, percentage etc.) using Microsoft Office Excel 2007. Second, to infer more subjective data pedagogical observation were recorded on a field notebook. Instruments and method are fully described in "Data analysis" (Section 2.3).

### 2.3.2. Didactic game

The second activity involved a play set designed to explore the relationship between society and nature, focusing on the historical

urbanization process of Guanabara Bay. This was done by means of a didactic game, which consists in a number of predefined educational goals presented to students in a playful way. The objective is that, by adding operational mechanisms of games to a class, a didactic game can cover certain topics of school curriculum while it encourages students' participation [42]. In this work, a board game titled "Guanabara Bay through Time" was used as a didactic game, and it functions as a chronological puzzle. A timeline is displayed on a board, highlighting key years in which historical events influenced the current state of Guanabara Bay. Each year is represented by two puzzle pieces: one with an image and the other with a corresponding text. The goal is to correctly associate the text and image cards with the relevant years on the timeline. For example, for the year 1502, students matched the text and image depicting the arrival of Portuguese caravels in Guanabara Bay. To complete the task, students were required to read, discuss, and collaborate within their groups. Each class was divided into groups, with each group receiving a game set. The allotted time for the activity was 45 min (Fig. 1).

Based on this timeline showing the economic development related to Guanabara Bay the game is focused in discussing themes directly related to principles 1 (concept G), 5 (concepts A and C), 6 (concepts D and F) and 7 (concept C) and related dimensions such as Awareness, Attitude, Behavior and Adaptive Capacity. Data collection on this activity was done solely on field notebook, since what was more important here was the dynamics created among students-game, students-students and students-researchers who conducted the playing.

### 2.3.3. Mock trial

The third activity of the intervention was a mock courtroom simulation that debated the dilemma between economic exploitation and environmental preservation of Guanabara Bay, examining its pros and cons. This teaching strategy, known as a Mock Trial, is a particular type of role-play activity where students can assume the roles of defendants and prosecutors in order to argue in relation to a pre-determined topic of discussion [78]. Therefore, it requires students to collaborate in developing arguments, encouraging them to organize and share their ideas, experiences, and perspectives on the proposed dilemma that relates to desired educational goals [78]. The activity promotes research, reading, discussion, and the development of argumentation skills and critical

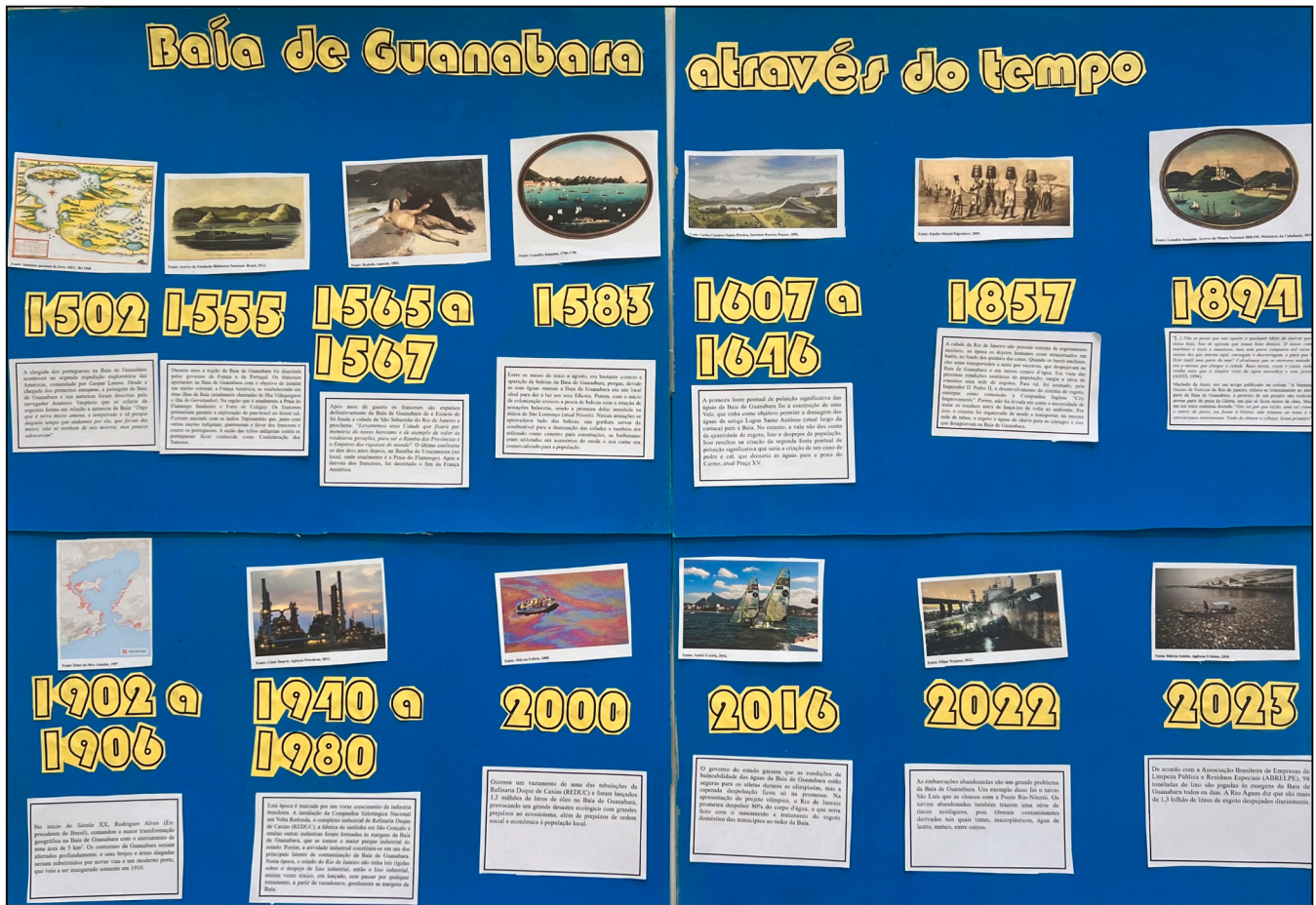


Fig. 1. Image of the board game “Guanabara Bay Through Time”, showing the pieces (images and text) correctly matched to their respective years.

thinking [67,78].

The Mock Trial activity was conducted over two class periods. The first session focused on organization and preparation. Students were randomly divided into two groups representing opposing interests. They were provided with short excerpts from news articles, research papers, and books to support their arguments. During this stage, teachers guided the reading process, clarified doubts, and assisted students in formulating their arguments.

The second session featured the Mock Trial itself. Each group had 5 min to present and defend their case, 3 min to raise objections, and 1 min to provide rebuttals. Teachers assumed the role of judges, delivering a verdict based on the presentations at the end of the activity.

Data collection and analysis was done by means of audio recordings of the sessions with further transcription which were analyzed using the IRAMUTEQ software, which employs the R interface for multidimensional textual analysis [15]. Word clouds were generated as part of this analysis, graphically representing terms with varying sizes based on their frequency. The textual analysis was performed separately for each class involved in the mock trial. Another important data source here was the notes on the dynamics of the activity registered in the field notebook.

### 2.3.4. Field trip

A field trip is an educational strategy that requires traveling beyond the school grounds in order to carry out practical activities in environments that directly relate to the proposed educational objectives [65]. In this sense, a field trip to Guanabara Bay was organized, as field-based learning fosters curiosity, aids in understanding abstract concepts, and provides students with diverse experiential opportunities [65].

The excursion included visits to three locations where students could

observe different societal interactions with Guanabara Bay: Parque da Cidade (a public park overlooking the Bay), the Z-8 Fishing Colony in Jurujuba, and the headquarters of the Aruanã Project (a sea turtle preservation project) (Fig. 2). Transportation for students and teachers was provided via a van to facilitate this activity. Verbal statements, body signals, manners and conduct was carefully registered in field notebook over the whole time of the excursion by the researchers.

### 2.3.5. Evaluation

To evaluate the effectiveness of the intervention, two questionnaires (pre-test and post-test, Table 2) were administered, with most questions being identical across both. In addition to assessing knowledge, awareness, attitude, access and experience, the post-test included questions to evaluate students' receptiveness to the various activities conducted during the intervention, specifically their emotional connection.

The pre-test consisted of 14 questions divided into three sections: 1) Personal Data - two questions regarding students' age and gender; 2) Socioeconomic and Biodiversity Aspects - four multiple-choice questions and three open-ended questions focused on Guanabara Bay's socioeconomic and biodiversity aspects; and 3) Opinions on Pollution and Preservation - three multiple-choice questions and two open-ended questions exploring students' opinions on pollution and preservation of Guanabara Bay.

The post-test excluded two questions related to socioeconomic aspects, as this information was already recorded in the pre-test. Five additional questions were added, focusing on students' opinions about the activities, suggestions for improvement, and highlights of the intervention, resulting in a total of 17 questions.

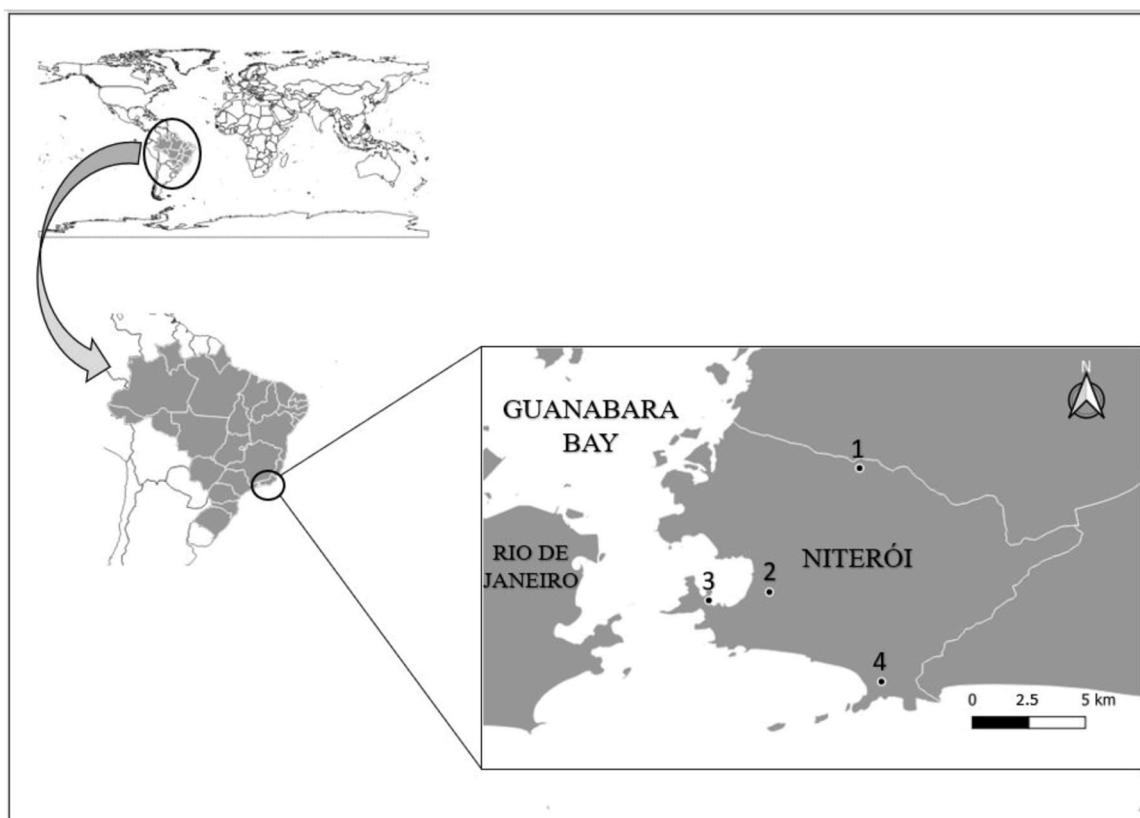


**Fig. 2.** Maps of Brazil (Left) and Niterói (Right) with the markings of departure point—the school (1) and the places visited: Niterói City Park (2), Fishing Colony (3), and Aruanã Project (4).

Teacher observations recorded in field notebooks were also considered in assessing the intervention's effectiveness. These notes provided valuable context by situating the study within a broader social and temporal framework and offered insights into students' opinions, interactions, and behaviors during the activities. This qualitative data helped evaluate the intervention's impact on dimensions such as behavior, adaptive capacity, activism, communication and trust and transparency [64].

#### 2.4. Data analysis

The data collection and analysis of this work was based on two methods. First a content analysis was applied to written (post-it's and questionnaires) and spoken registers (Audio recording of the mock Trial) in order to systematize the explicit content of these communications [8]. These was done reading the entire corpus of documents was read to get acquainted with the words and expressions therein; then, relevant words/fragments/themes were defined according to their direct connection with the goals of the study or the content to which they refer. After that, these words/fragments/themes were registered according to diversity (different words/fragments registered concerning the same theme) and citation (numbers of times they were cited). Only words/fragments explicitly related to a theme debated or scrutinized were retained, ruling out those transversely related to the subject, so that ambiguous results could be avoided. Regrouping could also be performed when new characteristics emerged during the analysis [40]. Readings were performed twice by one of the researchers (VHCV), and a third time by a third part (LRMN). Results from the three readings of the documents were considered consistent with less than an average of 1 % difference between the three different readings. Based on these procedures categories were created and quantified [40].

Quantitative descriptions of the results obtained from content analysis of post-it's and questionnaires were submitted to simple statistic and qui-square test when were identified relevant differences in the frequencies registered among categories. However, in such cases the statistical results were taken as one more evidence composing a complete set of interconnected evidences or illustrating trends. All quantitative descriptions were done using software Microsoft Excel 2007. Regarding more extensive textual corpus as was the case for the audio recording of the mock trial the option was to use the software IRAMUTEQ 0.7 alpha 2 (Interface de R pour les Analyses Multidimensionnelles de Textes et de Questionnaires), which informs the relationships between the words most frequently enunciated by the individual or group in order to understand the structure and organization of the debate [15]. In this study, each section of the mock jury represents one textual corpus. Word clouds were generated as part of this analysis, graphically representing terms with varying sizes based on their frequency, which can define the main patterns in a text [23] and, in this sense, suited to identify the specific points of the discussion in which students were most engaged.

Secondly the pedagogical field notes were used in order register verbal and non verbal manifestations coming from students as well as their educational environmental context. Also registered were the thoughts, feelings, impressions and perceptions of the researcher at those moments. All of this information helped to frame the study within a broader social and temporal context [47,63]. In this sense, the interpretation of data collected by field notebooks can serve as an inquiry instrument on the dimensions of OL, especially activism, adaptive capacity, emotional connections, and trust and transparency, which are hard to measure when only using quantitative methods [75]. Furthermore, it is important to say that due the fact that our results are mainly exploratory and based on multiple instruments and different analysis the triangulating of quantitative and qualitative (classroom observations, student reflections etc.) was done every time it was possible to enrich

**Table 2**

Type of questions applied in pre- and post-tests and respective dimensions of Ocean Literacy covered.

| Questions                                                                                             | Type            | Pre-test | Post-test | Dimensions                                                  |
|-------------------------------------------------------------------------------------------------------|-----------------|----------|-----------|-------------------------------------------------------------|
| 1) Age                                                                                                | Open question   | ✓        | ✓         | X                                                           |
| 2) Gender                                                                                             | Multiple-choice | ✓        | ✓         | X                                                           |
| 3) Do you know Guanabara Bay?                                                                         | Multiple-choice | ✓        | ✓         | Knowledge<br>Awareness<br>Access and experience             |
| 4) Which living beings do you think are present in Guanabara Bay?                                     | Open question   | ✓        | ✓         | Knowledge<br>Awareness                                      |
| 5) Which ecosystems are present in Guanabara Bay?                                                     | Multiple-choice | ✓        | ✓         | Knowledge<br>Awareness<br>Emotional                         |
| 6) How often do you go to Guanabara Bay?                                                              | Multiple-choice | ✓        |           | Connections<br>Access and experience                        |
| 7) Do you believe that Guanabara Bay is important for your city? If so, explain why.                  | Open question   | ✓        | ✓         | Knowledge<br>Awareness<br>Attitude                          |
| 8) Which professions or forms of work related to Guanabara Bay do you know?                           | Open question   | ✓        | ✓         | Knowledge<br>Awareness                                      |
| 9) Do you practice any leisure activities in Guanabara Bay?                                           | Open question   | ✓        |           | Emotional<br>Connections<br>Access and experience           |
| 10) Do you believe that Guanabara Bay is polluted?                                                    | Multiple-choice | ✓        | ✓         | Knowledge<br>Awareness<br>Attitude                          |
| 11) If so, what do you think causes this pollution?                                                   | Open question   | ✓        | ✓         | Knowledge<br>Awareness<br>Attitude                          |
| 12) What are the consequences of pollution in Guanabara Bay?                                          | Open question   | ✓        | ✓         | Knowledge<br>Awareness<br>Attitude                          |
| 13) Do you think Guanabara Bay should be preserved?                                                   | Multiple-choice | ✓        | ✓         | Knowledge<br>Awareness<br>Attitude                          |
| 14) How important is the preservation of Guanabara Bay to you?                                        | Multiple-choice | ✓        | ✓         | Knowledge<br>Awareness<br>Attitude<br>Emotional             |
| 15) What note would you give to the proposed activities related to Guanabara Bay?                     | Multiple-choice |          | ✓         | Connections<br>Emotional<br>Access and experience           |
| 16) Justify your note                                                                                 | Open question   |          | ✓         | Emotional<br>Connections<br>Access and experience           |
| 17) Which of these activities was your favorite?                                                      | Multiple-choice |          | ✓         | Emotional<br>Connections<br>Access and experience           |
| 18) Do you believe that you learned something from the activities conducted? Explain your answer.     | Open question   |          | ✓         | Knowledge<br>Awareness<br>Attitude<br>Access and experience |
| 19) Write your opinion or a suggestion regarding the activities that were conducted on Guanabara Bay. | Open question   |          | ✓         | Emotional<br>Connections<br>Access and experience           |

**Table 3**

Methods, instruments used to data collection and undertaken analysis for each of the activities done in the Ocean Literacy intervention. Number in brackets after activities stands for research questions (RQ) addressed 1- Can an OL intervention provide students with a historical perspective on the influence of the society-nature relationship on the current state of Guanabara Bay?; 2- Are teaching activities that address the society-nature relationship effective in fostering more engaged opinions about preserving marine environments?; 3- How do students evaluate the intervention?.

| Method                   | Instrument                 | Analysis               | Activity (RQ)       |
|--------------------------|----------------------------|------------------------|---------------------|
| Content analysis         | Written record (post-it's) | Descriptive statistics | Brainstorm (2)      |
|                          | Audio recording            | Wordcloud              | Evaluation (3)      |
|                          | Questionnaires             | Descriptive statistics | Mock Trial (2)      |
|                          |                            |                        | Pre-test (2)        |
| Pedagogical observations | Field notebook             | Interpretative         | Post-test (1, 2, 3) |
|                          |                            |                        | Evaluation (3)      |
|                          |                            |                        | Pre-test (2)        |
|                          |                            |                        | Post-test (1, 2, 3) |
|                          |                            |                        | Brainstorm (2)      |
|                          |                            |                        | Didactic game (1)   |
|                          |                            |                        | Mock Trial (2)      |
|                          |                            |                        | Field trip (1)      |
|                          |                            |                        | Evaluation (3)      |
|                          |                            |                        |                     |
|                          |                            |                        |                     |
|                          |                            |                        |                     |

and nuance the findings. Table 3 shows a summary of the data analysis undertaken and how they are linked to the research questions proposed.

### 3. Results

#### 3.1. Sample characterization

A total of 31 students, aged 14–17 years, participated in the activities (Fig. 3A). Most of the participants (68 %) were male (Fig. 3B). When responding to question 6 of the pre-test (“How often do you go to Guanabara Bay?”), 45 % of students indicated that they have never visited the Bay, while only 3 % reported going there daily (Fig. 3C). Similarly, for question 9 (“Do you practice any leisure activities in Guanabara Bay?”), 87 % of students answered that they do not.

#### 3.2. Brainstorming

A total of 36 words were mentioned during the brainstorming activity, with the most frequent being sea (15 mentions), water (10 mentions), fish (8 mentions), and boats (8 mentions), as illustrated in the bar graph below (Fig. 4).

The terms were grouped into five categories: economic activity, pollution, affective aspects, environment, and biodiversity. Among these, economic activity and environment accounted for the highest number of mentions, distributed across various terms (27.8 % and 22.2 %, respectively). The detailed results are presented in Table 4.

#### 3.3. Didactic game

According to the field notebook records, the activity “Guanabara Bay Through Time” revealed that students could associate images and texts related to recent topics such as pollution, marine litter, floods, and ghost ships, which are linked to events from the late 20th century onward. However, they had trouble identifying older historical events (16th to early 20th century), such as the landfilling of the Bay, the construction of the city’s sewage system, and the exploitation of natural resources, including whaling (Table 5).

As the game progressed and teachers provided guidance, students began to understand the connection between historical events and the Bay’s current state, recognizing the historical nature of the urbanization process. Notably, students expressed surprise and indignation upon

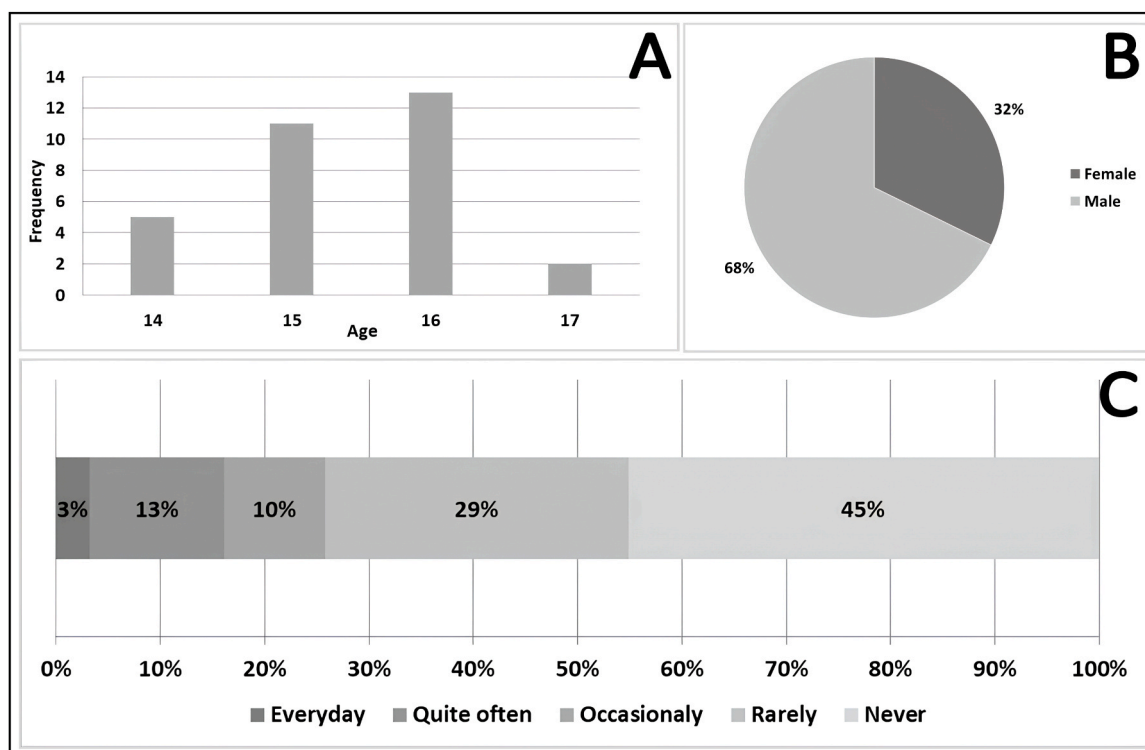


**Fig. 3.** Sample characterization regarding (A) Age distribution of students who participated in the activities; (B) Gender of students who participated in the activities; (C) How often students go to Guanabara Bay (GB).

learning that Guanabara Bay once supported a high density of mangroves, as well as abundant populations of dolphins and whales.

After the activity, teachers facilitated a discussion emphasizing the relationship between society and nature in Guanabara Bay. During this discussion, students demonstrated an understanding that past events significantly influence current issues, such as flooding, beach swimming suitability, and biodiversity decline.

### 3.4. Mock trial

In this activity, two classes (4 A and 4B) engaged in similar discussions about the dialectic between exploration and conservation of Guanabara Bay, with a primary focus on fishing, as shown in Fig. 5. Class 4 C, while also emphasizing fishing, broadened the discussion to include additional aspects such as the oil and gas industry.

In classes 4 A and 4B, the groups initially adopted extreme positions, with each side heavily blaming the opposing party. This required teacher intervention to recap and clarify the arguments presented by both sides. By the end of the discussion, the groups reached a consensus that exploration and conservation must achieve a balance. The activity encouraged students to develop communication skills by constructing arguments and counterarguments, which necessitated engaging with new information and alternative perspectives, thereby enhancing their adaptive capacity. Additionally, trust and transparency were addressed by discussing the reliability of the information sources used, including scientific articles, official publications, and credible reports from mainstream media.

In class 4 C, the group representing workers demonstrated a utilitarian perspective on natural resources, defending all forms of commercial exploitation, including the oil and gas industry, tourism, and fishing. In contrast, the environmentalist group adopted a more rigid stance, even questioning the impacts of artisanal fishing—a form of commercial exploitation generally recognized as low-impact or even sustainable.

### 3.5. Field trip

The first stop on the field trip was Parque da Cidade, located at the top of Morro da Viração, offering an expansive view of Guanabara Bay. At this location, students were asked to observe the Bay and describe what they saw in the landscape. Their responses included “barges, cargo vessels, oil vessels, the Rio-Niterói bridge, and fishing boats”. When asked if their observations shared anything in common, the students quickly identified that these activities contribute to pollution. However, when questioned further about why they thought so, the students were unable to articulate a clear explanation.

This prompted a discussion where it was highlighted that, except for fishing, the activities mentioned represented commercial enterprises that exploit the Bay’s natural resources primarily for their exchange value (profit) rather than their use value. This distinction laid the groundwork for understanding the economic relationship between society and nature.

The second stop was the Z-8 Fishing Colony in Jurujuba, where students interacted with shellfish gatherers and fishers to learn about the culture of artisanal fishing. At the colony, a representative from the Association of Shellfish Farmers and Artisanal Fishermen of Jurujuba (AMPAJ) explained the community’s subsistence relationship with the Bay. Following this discussion, the students visited the Jurujuba pier which is used by the fishermen, where they observed the day’s catch and learned about some of the many fish species present in the Bay. When asked how many fish were typically caught each day, a fisher responded, “In artisanal fishing, we only catch what nature offers us.” This interaction allowed students to experience a society-nature relationship emphasizing the use value of marine resources, which promotes sustainable behaviors like responsible fishing practices.

The final stop was the headquarters of the Aruanã Project, where students learned about research and conservation efforts focused on sea turtles that use Guanabara Bay for refuge and foraging. Volunteers from the project led the visit, emphasizing an individualistic approach to environmental preservation, such as encouraging citizens to pick up

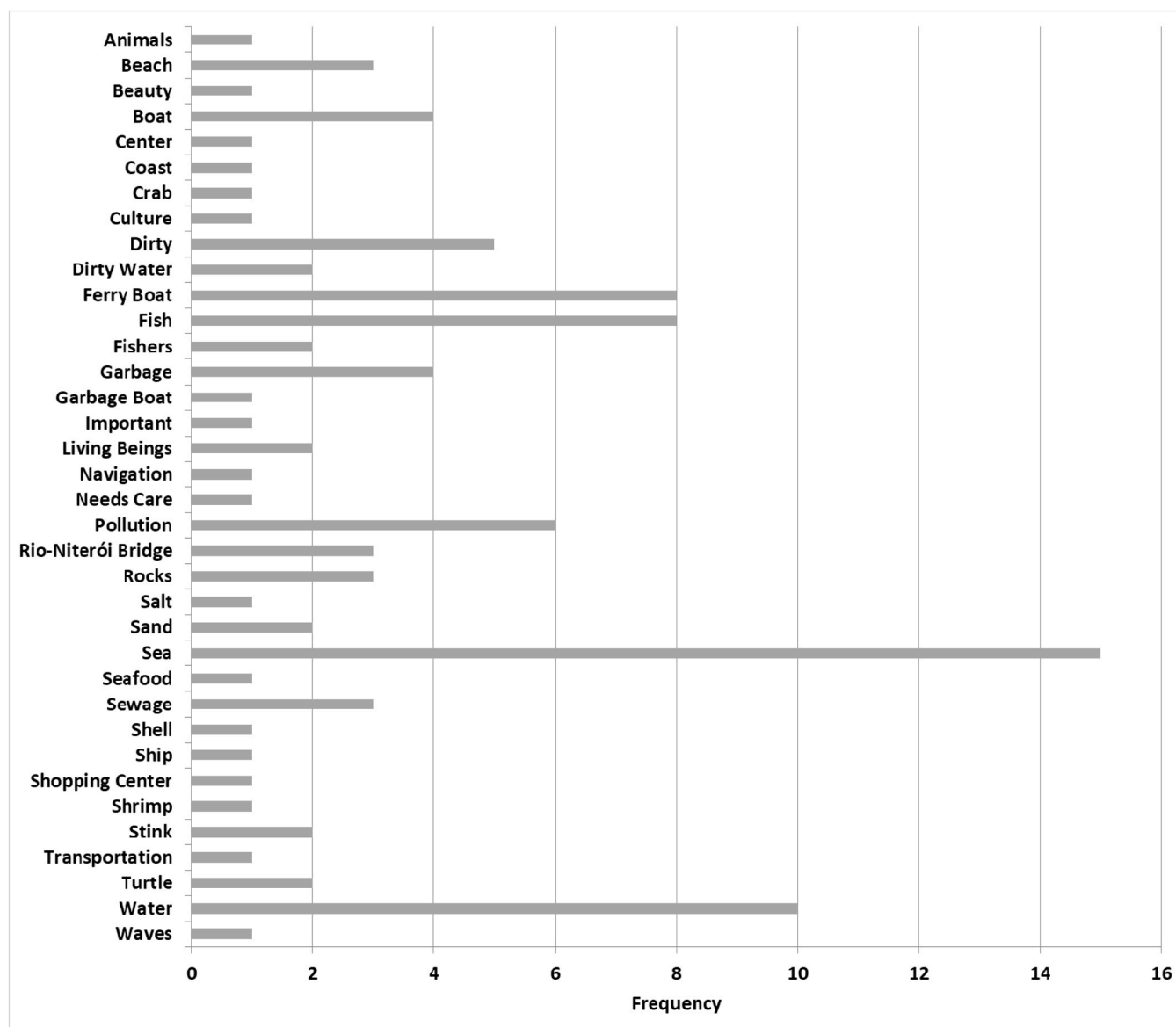


**Fig. 4.** Frequency of occurrence of words mentioned during brainstorming.

litter on beaches and conserve water during daily activities like showering. While students acknowledged the value of the project, they remarked on the way back to school that the volunteers' perspective seemed overly simplistic with one of the students saying that "*volunteers have a naive relationship with the ocean*". They argued that preserving the marine environment requires more than changes in individual habits and instead calls for a redefined society-nature relationship involving political and economic reforms (activism). [Table 6](#) summarizes the activities conducted during the field trip.

### 3.6. Evaluation

A comparison of the responses to the pre- and post-test questionnaires revealed that before the intervention most of the students were unfamiliar with Guanabara Bay. However, at the end of the activities students perception were substantially different, since in answering question 3 of the post-test ("Do you know Guanabara Bay?") most of them began to answer affirmatively. This result was reinforced by the fact that throughout the intervention, the students began to discuss and speak more confidently about Guanabara Bay, showing greater mastery on the issues related to it. Adding to that in answering question 13 ("Do

you think Guanabara Bay should be preserved?”) students also gave a higher number of answers supporting the conservation of Bay, as well as for question 14 (“How important is the preservation of Guanabara Bay to you?”), for which at the first place most students initially recognized the importance of preserving the Bay, but they did not consider it particularly relevant to them personally, but after the intervention, the majority expressed that the preservation of Guanabara Bay was extremely important (Fig. 6).

For question 10 (“Do you believe that Guanabara Bay is polluted?”), 11 (“What do you believe causes the pollution of Guanabara Bay?”), and 12 (“What are the consequences of pollution in the Bay?”), no statistically significant differences were found. However, there was an expansion in the variety of responses in the post-test, suggesting an increase in students’ knowledge about the Bay’s polluting agents (Table 7) and their adverse effects, such as threats to biodiversity, health hazards, harm to economic activities, and risks to human life.

Regarding biodiversity, it was not possible to identify statistically significant improvements in students' understanding of the biodiversity present in Guanabara Bay, as indicated by responses to questions 4 and 5.

When asked about professions and forms of employment related to

**Table 4**

Words cited during brainstorming, their categorization, number (N), and percentage (%) per category.

| Category            | Words               | N  | %    |
|---------------------|---------------------|----|------|
| Economic Activities | Ferry Boat          | 10 | 27.8 |
|                     | Boat                |    |      |
|                     | Center              |    |      |
|                     | Seafood             |    |      |
|                     | Navigation          |    |      |
|                     | Ship                |    |      |
|                     | Fishermen           |    |      |
|                     | Shopping Center     |    |      |
|                     | Rio- Niterói Bridge |    |      |
| Pollution           | Transportation      |    |      |
|                     | Dirty Water         | 7  | 19.4 |
|                     | Garbage Boat        |    |      |
|                     | Sewage              |    |      |
|                     | Stink               |    |      |
|                     | Garbage             |    |      |
| Affective Aspects   | Pollution           |    |      |
|                     | Dirty               |    |      |
|                     | Beauty              | 4  | 11.2 |
|                     | Culture             |    |      |
|                     | Important           |    |      |
| Environment         | Needs Care          |    |      |
|                     | Water               | 8  | 22.2 |
|                     | Sand                |    |      |
|                     | Coast               |    |      |
|                     | Sea                 |    |      |
|                     | Waves               |    |      |
|                     | Rocks               |    |      |
|                     | Beach               |    |      |
| Biodiversity        | Salt                |    |      |
|                     | Animals             | 7  | 19.4 |
|                     | Shrimp              |    |      |
|                     | Shell               |    |      |
|                     | Fish                |    |      |
|                     | Crab                |    |      |
|                     | Living Beings       |    |      |
|                     | Turtle              |    |      |
| Total               |                     | 36 | 100  |

Guanabara Bay (Question 8), students identified occupations in three main categories: industry and transportation (e.g., oil workers, boiler-makers, boat captains); fishing and extraction (e.g., fishers, shellfish gatherers, crab collectors); and science (e.g., researchers). For Question 7, which explored the importance of the Bay for surrounding cities, students mentioned its roles in food supply, transportation, leisure, employment, and tourism.

Regarding the intervention activities, 80 % of students expressed that they enjoyed the activities and found them valuable for learning. They highlighted that the activities provided “access and experience” to the practical knowledge, critical discussions, and engaging playful experiences. The remaining 20 % reported difficulties in understanding some activities or expressed interest only in those directly related to biodiversity (Table 8).

When asked about their favorite activity, students most frequently cited field trips (38 %) and educational games (31 %) as their top choices (Fig. 7).

When asked how much the intervention had benefited their learning

(Question 18), 90 % of the students reported that the activities helped them understand the historical processes of urbanization and industrialization of the Bay, as well as its significance to the population. As a result, they expressed a greater commitment to its preservation. In their final comments, students praised the intervention and suggested incorporating a boat trip to the Bay as part of the activities.

In order to picture the classroom engagement and give examples of students participation under the activities, Table 9 aligns the objective of this work with the research questions and some statements “flags” collected under the intervention experience showing emerging insights of outcomes (e.g., emotional impact, critical thinking) which were happening.

#### 4. Discussion

There is a consensus among political and scientific communities that effective conservation measures for marine environments depend on understanding the relationships between society and nature [36,37,50, 56]. In this context, the United Nations Decade of Ocean Science for Sustainable Development – Ocean Decade (2021–2030) and the UNESCO International Committee for Oceanography [34] have highlighted Ocean Literacy (OL) as a key tool to help understand and reorganize these relationships, particularly those involving marine and coastal environments. In recent years, numerous formal, non-formal, and informal educational projects have been developed to clarify the society-nature relationship and to cultivate informed citizens capable of making decisions that support the conservation of oceans and their resources [11,52,61]. This study implemented a formal educational intervention on OL to critically address the relationship between society and nature in order to engage students from elementary level (12–15 years old) in marine sustainability, since they have been recognized as influential opinion-makers [6], therefore, they are expected to function as agents of change, shaping perspectives, opinions, and worldviews not only among their school peers but also within their families [10].

Furthermore, the initiative sums to the efforts that have been implemented in Brazil to foster OL such as the “Maré de Ciência” (Science Tide) program from Universidade Federal de São Paulo (State University of São Paulo) which aims to enforce the link among public policies, science and society [76]. They created a network among mayors, public managers, civil society and private initiatives called “Aliança Brasileira pela Cultura Oceânica” (Brazilian Alliance for Ocean Literacy) and are also implementing the project “Escola Azul Brasil” (Blue School Brazil) to include OL activities in schools. More recently, one of the main institutional education and research funding agency in the country (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – CAPES) announced the first course on “Ocean Literacy and Sustainability” for elementary school teachers [18]. In this way, the present work represents a concrete experience on how to apply OL activities integrated in an educational intervention using students’ local experiences to discuss global problems concerning ocean, resources use and sustainability. Even more, the educational intervention described planned, applied and evaluated here was concerned with children in state of school retention, who represent 13.3 % of all students in the country (United Nations Agency for Children – [77]).

**Table 5**

Degree of difficulty in associating pieces to years by students. The color gradient indicates years in which students had the greatest difficulty (Black: difficult, Gray: Intermediate, White: Easy).

|               | 1502 | 1555 | 1565-1567 | 1583 | 1607-1647 | 1857 | 1894 | 1902-1906 | 1940-1980 | 2000 | 2016 | 2022 | 2023 |
|---------------|------|------|-----------|------|-----------|------|------|-----------|-----------|------|------|------|------|
| <b>FIGURE</b> |      |      |           |      |           |      |      |           |           |      |      |      |      |
| <b>TEXT</b>   |      |      |           |      |           |      |      |           |           |      |      |      |      |

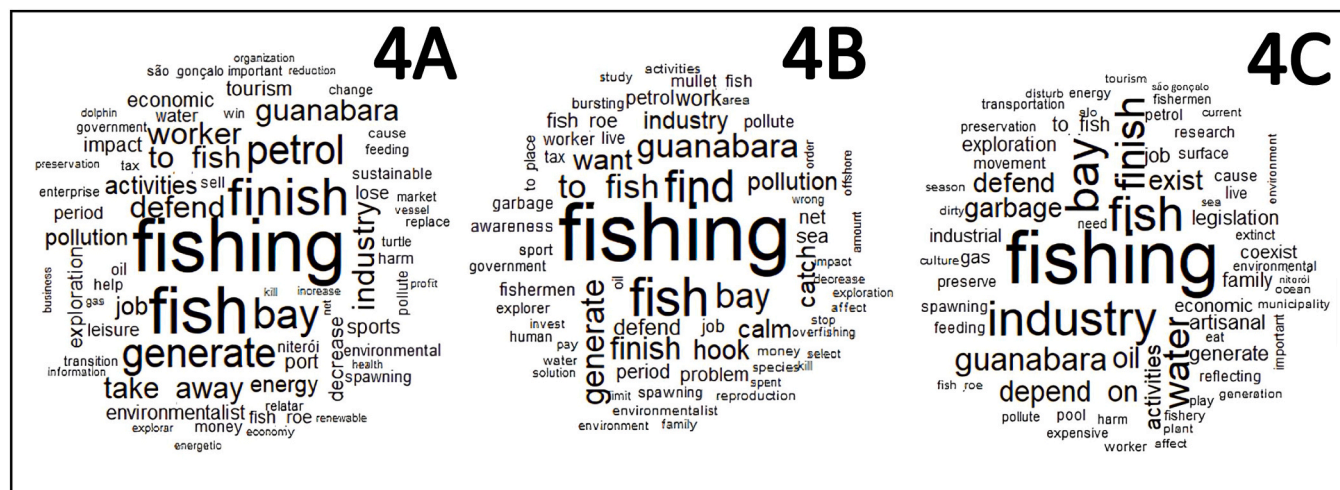


**Fig. 5.** Word clouds from students' recurring references in mock trial discussions for classes 4 A, 4B, and 4 C.

Table 6

Distances (km) between points visited (above diagonal), time spent (min) at each location (first column), and activities conducted (last row).

|                  | School        | Parque da Cidade                  | Z-8 Colony                                                          | Aruanã Project |
|------------------|---------------|-----------------------------------|---------------------------------------------------------------------|----------------|
| School           | 0             | 9.9                               | 13                                                                  | 17.7           |
| Parque da Cidade | 45            | 0                                 | 6                                                                   | 13.9           |
| Z-8 Colony       | 90            | X                                 | 0                                                                   | 14             |
| Aruanã Project   | 30            | X                                 | X                                                                   | 0              |
| Activities       | -<br>Boarding | - Observation<br>- Talking circle | - Visit to the pier<br>- Talking to shellfish gatherers and fishers | - Guided tour  |

The importance for OL of bringing regional and local environments to discuss global problems have been pointed in literature [9,28,53]. In debating local problems students are more willing to recognize the relevance of the marine environments in their daily lives. During this intervention, an early discussion revealed that many students perceived Guanabara Bay primarily as a “backdrop” for economic activities, with comments such as “*Is that what’s under the Rio-Niteroi bridge?*” or “*I’ve passed by it on the boats*”. Others described the Bay as a repository for pollution, noting, “*What I see most in the Bay is pollution*”. However, while students identified environmental degradation and economic activities, they did not connect the two, often attributing the Bay’s current state to individual behaviors rather than systemic issues.

Ocean Literacy interventions worldwide have been trying to

implement a critical approach. One tool used in this effort is to incorporate playful elements. For example, Gao et al. [30] developed a board game linking urban development to increased risks of natural disasters, using the case of the Yudai artificial trench, which disappeared under Guangzhou's rapid urban expansion in China. Similarly, García & Miralles [31] created the Game of the Sea to address Ocean Literacy, using questions on topics such as art, literature, biology, chemistry, and physics to change students' perspectives on marine conservation. In this study, the game "Guanabara Bay Through Time" was able to show positive achievements related to the proposed objectives. Although our data are exploratory and limited in scope, it was possible by the end of the activity recognize that students were grasping that historical exploitation events directly contributed to the Bay's current degradation. Moreover, they understood that they, too, are affected by the

Table 7

Categories of students' responses about polluting agents in Guanabara Bay.

| Category                          | Pre-test | Post-test |
|-----------------------------------|----------|-----------|
| Population                        | ✓        | ✓         |
| Sewage                            | ✓        | ✓         |
| Industry                          |          | ✓         |
| Garbage                           | ✓        | ✓         |
| Oil spill                         | ✓        | ✓         |
| Landfilling                       |          | ✓         |
| Exploitation of natural resources |          | ✓         |
| Did not know how to answer        | ✓        | ✓         |
| <b>Total</b>                      | <b>5</b> | <b>8</b>  |

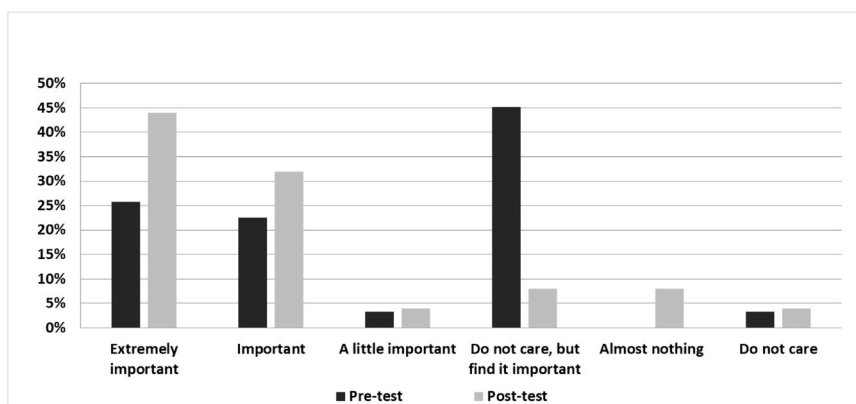


**Fig. 6.** Comparative histogram of students' answers in pre- and post-tests for question 14.

**Table 8**  
Students' notes on the activities performed during the intervention (5- I liked everything; 4- I liked almost everything; 3- I liked only some activities; 2- I liked almost nothing; 1- I liked nothing), along with their frequencies and justifications.

| Note for Activities | F    | Justifications                                                                     |
|---------------------|------|------------------------------------------------------------------------------------|
| 5                   | 64 % | - New experiences<br>- New practical pieces of knowledge<br>- Liked all activities |
| 4                   | 16 % | - Only liked the experimental activities<br>- Did not participate in all classes   |
| 3                   | 16 % | - Did not like all the classes<br>- Difficulty in understanding some activities    |
| 2                   | 4 %  | - Only got interested in biodiversity-related activities                           |
| 1                   | 0 %  | X                                                                                  |

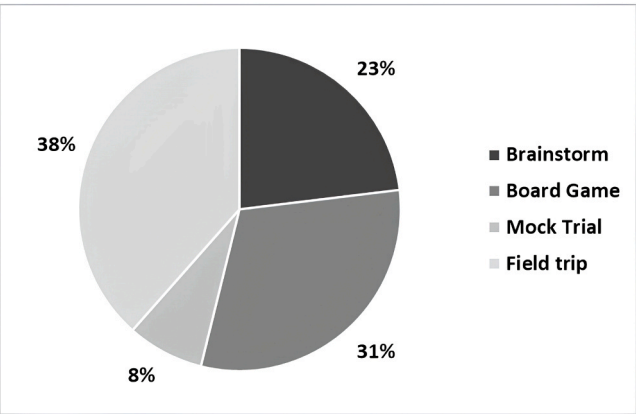


**Fig. 7.** Students' responses to question 17 (What was your favorite activity?).

environmental issues facing Guanabara Bay.

Environmental degradation is a direct consequence of the relationships established between society and nature, particularly through human activities based on the exploitation of natural resources, such as industry, fishing, and tourism. Role-play activities, where participants assume the roles of characters or groups in specific scenarios, have proven effective in clarifying the interdependence between society and nature. For example, Weines [79] used the 1989 cod stock crisis in Norway, caused by overfishing, to simulate negotiations among stakeholders, including artisanal fishers, industrial fishers, researchers, and representatives of coastal communities. The goal was to establish fisheries management strategies that balanced economic, environmental, and social interests. Similarly, Koenigstein et al. [41] developed a role-playing game (RPG) called Ocean Limited to teach high school students about society-ocean relationships, marine sustainability challenges, and climate change. In this game, students assume roles such as scientist, mayor, fishing industry representative, artisanal fisher, or tourist, and must cooperate to develop sustainable ocean-use strategies. In this study, a mock trial was employed to foster a critical perspective on the tension between conservation and exploitation of Guanabara Bay. During the activity, students with initially extremist and intransigent opinions came to have softer positions once the activity highlighted that the social function of marine resource exploitation can align with conservation when guided by the needs of communities or social groups that prioritize survival over wealth accumulation, as exemplified by artisanal fishing.

Field trips are commonly integrated into Ocean Literacy initiatives, such as the work by Ferreira et al. [24], who conducted two field trips as part of the non-formal education project Biodiversity Ambassadors. The aim was to demonstrate fishing techniques used by local communities and display the biodiversity of the rocky coasts in the Torres Vedras and Lourinhã region (Portugal), raising awareness about conserving coastal

**Table 9**  
Alignment of the objective of the work, research questions and student's statements collected during the educational intervention.

| Objective                                                            | Research Question                                                                                                                                                                                      | Brainstorm                                                                                             | After                                                                                                                                                                                                                                                                                                        |
|----------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| To offer a historical perspective of the society-nature relationship | Are teaching activities that address the society-nature relationship able to give students a perspective beyond individualistic, utilitarian and pragmatic of management and use of natural resources? | - "(Guanabara Bay) Is that what's under the Rio-Niteroi bridge?"<br>- "I've passed by it on the boats" | - "If there is a lot of trash and pollution, there will be few marine life" (Board game)<br>- "I think, like, you shouldn't stop fishing, but you could decrease the amount of fishing in certain months" (Mock Trial)<br>- "The (project) volunteers have a naive relationship with the ocean" (Field Trip) |
|                                                                      | Can an OL intervention based on local problems favour student's comprehension of a historical nature of the society-nature relationship?                                                               | - "What I see most in the Bay is pollution"                                                            | - "The Bay had whales and dolphins in the past?" (Board game)<br>- "The pollution was caused by humans" (Board game)<br>- "Part of the Fonseca neighborhood is land-filled" (Board game)                                                                                                                     |
|                                                                      | How do students evaluate the intervention?                                                                                                                                                             | X                                                                                                      | - "I found these activities very important; they gave me a new perspective on my city and Guanabara Bay" (Post-test)                                                                                                                                                                                         |

and oceanic resources while preserving the community's cultural values. Similarly, Lai [44] described how a boat trip along Taiwan's Tamsui River, and the New Taipei Estuary provided students with insights into the relationships between the environment, culture, and industrial development. In this study, the field trip to Guanabara Bay was crucial for illustrating the diverse interactions between society and nature. Students applied their knowledge to identify and interpret how artisanal fishers, fish farmers, and researchers use the Bay as a resource for work.

The comparison between pre- and post-test results revealed improvements in the dimensions of knowledge, perception, attitude, and emotional connections. Students' perspectives shifted, transforming the Bay from a body of water they felt no connection with – and whose preservation seemed irrelevant – into a resource they now viewed as critically important. Notable qualitative improvements were observable in responses about the causes of pollution in Guanabara Bay, however changes in knowledge, perception, and attitude regarding pollution were discrete. Despite this, students demonstrated a broader understanding than before about the agents contributing to pollution.

These composed findings suggest that the intervention successfully fostered a historical-critical perspective on society-nature relations in Guanabara Bay. As one student remarked in the post-test questionnaire: "I found these activities very important; they gave me a new perspective on my city and Guanabara Bay". Similar results have been reported in other studies. For instance, Bettencourt et al. [10] worked with students from a public school on Madeira Island (Portugal) and confirmed their hypothesis that a combination of theoretical, laboratory, and practical activities focusing on the risks of marine debris would improve students' knowledge, perception, and behavior. They found statistically significant differences between pre- and post-test responses regarding the decomposition time of beach litter, its journey to the ocean, and its

environmental impacts. Likewise, Mokos et al. [53] observed statistically significant improvements in an elementary school in Zahar (Croatia) in the understanding of Ocean Literacy principles after non-formal activities addressing the food chain, marine biodiversity, overfishing, and ocean acidification. Their study found marked differences in knowledge about Principle 4 (The ocean makes the Earth habitable) and Principle 5 (The ocean supports immense biodiversity and ecosystems).

In recent years, OL educational actions have increased in frequency and, more than that, they have adopted different strategies to promote awareness about the marine environment [9,25,49,61]. One example is citizen science initiatives, which are expected to develop students' skills that will allow them to observe local changes in ecosystems caused by global phenomena such as climate change and plastic pollution [11,73,74]. Another example is the dealing with the marine environment as a socio-scientific issue, understanding the demand imposed on the younger segments of the population to be prepared from a theoretical and practical point of view to deal with the consequences of a marine environment in an advanced state of degradation [66]. The fact that the ocean is increasingly affected by environmental impacts resulting from human action highlights the importance of engaging different educational segments in marine sustainability actions, which can be done through teaching methodologies that develop students' autonomy in the face of oceanic problems, such as active learning methodology. By encouraging communication, problem-solving and critical thinking, OL actions that use active learning can stimulate these skills in students, with the aim of building an oceanic citizenship that mobilizes itself in the face of the connection between oceanic destruction and the current society-nature relationship. Consideration of the influence that the social environment has on the marine environment is also present in the Ocean Decade, which defined ten challenges to be overcome in order to achieve the "ocean we want", with the tenth challenge pointing to the need for a radical change in humanity's relationship with the ocean. According to UNESCO initiative, the intended transformation would occur through stimulating behavioural changes through Ocean Literacy actions [35].

Another initiative that the intervention employed here maintains relation is the experience of "Blue Schools" that comes from Portugal which uses a holistic and interdisciplinary perspective. Oceanic themes are there presented in problem situations that encourage students to use a think-action strategies using formulations through areas such as Ocean Literacy, scientific literacy, education for sustainable development and citizenship education [21]. In the present work, the degraded situation of Guanabara Bay was discussed based on the elucidation of the historical process that led to the current condition, involving formulations on the bioecological characteristics, the environmental impacts generated by its exploration and occupation, and the different ongoing economic enterprises in the Bay. In this sense, the experience described reveals relations with the experience of "Blue Schools".

At this point, it is important to discuss some limitations regarding the process of planning and executing the educational intervention employed. First of all, not all seven principles and 45 concepts were addressed during the implementation of the five activities as well as was not possible to mobilize or evaluate the mobilization of all ten OL dimensions. Time was possibly an important limiting factor since the intervention lasted only 5 meetings (480 min) contrasting with other long term actions [10,57,61]. As an extension of this the number of teaching strategies was also limited, which may have defined that mobilization of some of the OL dimensions was lacking or have not delivered as good results as would be the case with a long term action with a much more diverse set of teaching strategies. Furthermore, the obtained results were also assessed under a limited number of assessment instruments, therefore, it is possible that some of the richness of the experience was lost due to the analytical instruments used. Another limitation concerns the mock jury, in which the reality of social use of a coastal ecosystem was simplified into two interest groups. The worrying

effect of simplifications is pointed out by Kelly et al. [38], stating that reducing the complexity of ocean issues to a single problem prevents the constitution of an OL with a holistic perspective. Unfortunately, it was necessary to make adjustments that would make the intended activity accessible both to time limits and the level of the audience composed of elementary school children [41]. Notwithstanding, this study was able to demonstrate how an Ocean Literacy intervention can cultivate a historical perspective on the relationship between society and nature. Initially, students exhibited little to no knowledge about Guanabara Bay, perceiving it merely as a polluted environment dominated by commercial activities, without recognizing its historical, social, cultural, or ecological significance. By the end of the intervention, students developed an understanding that the Bay's current state is the result of a series of historical events tied to urban and industrial development. At the outset, students primarily attributed the degradation of Guanabara Bay to individual actions. However, after the Ocean Literacy intervention, their perspective shifted to a more historically informed understanding of the relationships between society, including various interest groups, and nature. The program also seems to have fostered changes in the dimensions of Emotional Connections and Attitude, as evident in students' re-evaluated positions on conservation and management actions. What was previously seen as irrelevant became recognized as critically important. Finally, although the intervention was framed within formal education, students overwhelmingly regarded it as a valuable part of their learning experience, particularly the field trips and recreational activities.

In summary, in this study was shown a short-term intervention in Ocean Literacy concerned with classes in situation of school retention and focused on the discussion about society-nature relationship. Based on a variety of different activities the intervention sought to mobilize all ten dimensions of Ocean Literacy what imposed data which were mainly exploratory. However, the compound evaluation of the different data sources and analysis have designed a positive evaluation of the educational intervention. We are convinced that the experience here in described can be very useful for all researchers, educators and managers of public policies interested in initiatives which accept the challenge of working Ocean Literacy in social engagement and in a multidimensional and exploratory way.

#### Author contributions

VHCV, LRMN and CEP contributed to data collection, EPS contributed to study concept and design, MRD contributed to data analysis. All contributed equally to interpretation, manuscript preparation, critical revision, and adding intellectual content.

#### CRediT authorship contribution statement

**Michelle Rezende Duarte:** Writing – review & editing, Project administration, Methodology, Formal analysis. **Luca Ribeiro Mendes Nicola:** Writing – review & editing, Supervision, Methodology, Investigation, Conceptualization. **Edson Pereira Silva:** Writing – review & editing, Writing – original draft, Supervision, Resources, Project administration, Methodology, Funding acquisition, Formal analysis, Conceptualization. **Carmen Edith Pazoto:** Writing – review & editing, Methodology, Investigation, Conceptualization. **Victor Hugo Cordeiro Vianna:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization.

#### Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Data availability

Data will be made available on request.

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