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"Why Has the Water Turned Green?" A Problem of Eutrophication in Primary School

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Abstract: This paper analyses how 224 students from the fifth and sixth grade recognise the key aspects, i.e., the causes, consequences, and solutions of the eutrophication problem affecting the relevant ecosystem in their region. Two instruments were used: a report sheet in which students work through the causes and consequences associated with the problem; and a personal letter addressed to the competent authority, which proposes solutions. The results show that students from the sixth grade recognised more complete interconnections between the agricultural development of the area and the changes that occurred in the ecosystem. In the identification of the key phases of the eutrophication process, students from both courses presented similar difficulties. Regarding the solutions, some reluctance was observed to limit agricultural activity. This reveals that students' social perceptions about the importance of agriculture for their region may be a possible influence on their solutions. Finally, five models were established regarding the understanding that students reach of the problem as a whole. More than half of students were included in the same model, comprising those who were able to adequately identify the causes and whole process of eutrophication, as well as those who defended the advantages of the proposed solution. Educational implications are discussed in this paper.

Keywords: eutrophication; primary school students; real problems

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Citation: Banos-González, I.; Esteve-Guirao, P.; Valverde-Pérez, M.; Ruiz-Navarro, A. "Why Has the Water Turned Green?" A Problem of Eutrophication in Primary School. *Sustainability* **2022**, *14*, 13651. https://doi.org/10.3390/su142013651

Academic Editors: Eija Yli-Panula and Eila Jeronen

Received: 28 September 2022
Accepted: 18 October 2022
Published: 21 October 2022

1. Introduction

Children are considered to be important actors for addressing socio-ecological issues. As present and future citizens, children are affected by environmental decision-making and have a right to be involved in the process [1,2]. In this sense, Ref. [3] offered a critique of traditional pedagogical approaches that may limit children's participation in society and does not invite them to think about, connect to, or act on socio-ecological issues in personally meaningful ways.

Therefore, there is a need to overcome educational approaches solely based on information about environmental issues, and commit to approaches that develop critical thinking and promote active participation and decision-making in real socio-ecological conflicts [4–7]. In this sense, Ref. [8] defended the need to develop systems thinking that allows the understanding of the complexity of these conflicts, and stated that the capacity of systems thinking should be based on critical thinking and reflection. For [9], sustainability education will be more effective if it incorporates systems thinking and action orientation. Likewise, Ref. [10] (p. 13) emphasised the need to provide students with skills as "consumers, producers, professionals, activists, policymakers, neighbours, employees, teachers and trainers, organisations, communities, and society at large" to have them embrace sustainability in their daily lives.

Hence, it seems essential that education provides young children with the knowledge, tools and skills to empower them "to become agents of change for the environment, capable of transforming the world around them" [11] (p. 3). For [12], this constitutes an essential dimension of scientific literacy and sustainability competence development. On the other hand, Ref. [11] pointed to the existing debate between the potential role of children as "agents of change for the environment" and their exposure to socio-ecological issues, which may cause them dread. In this sense, the World Organisation for Early Childhood Education (OMEP) defends young children's abilities to talk about socio-ecological issues [13]; however, it should be carefully addressed by the school. It also means that educators need to reassess their pedagogies in relation to what might be considered suitable contents, methods, and assessment practices regarding these issues [11].

2. Theoretical Framework

2.1. Educational Interest of Eutrophication Occurred in the Mar Menor Coastal Lagoon

Mar Menor is a Mediterranean coastal lagoon located in the southeast of Spain, that benefits from national and international protection figures [14]. Since mid-2015, this ecosystem has been suffering from a serious eutrophication crisis, although the first signs of the ecosystem's changes date back to the 1970s [15].

This situation has generated an intense debate among politicians and citizens, which should spread to the classrooms [16]. Among other reasons, this debate responds to the complex relationship of the causes and is especially linked to the agricultural intensification of the surrounding area, with strong environmental, social, and economic consequences [17,18].

Specifically, as a result of the entry of nutrients from the agricultural fields in the area, the concentration of nitrogen and phosphorus in the lagoon water has significantly increased [19,20]. These excess nutrients (nitrogen and phosphorous) stimulate the growth of phytoplankton and, indirectly, the bacteria thriving on the seafloor that feed upon the sinking phytoplankton. This hinders the entry of light, therefore hindering photosynthesis. Eutrophication ultimately causes hypoxia in the bottom waters as the bacterial metabolism depletes oxygen levels [21]. After years of apparent equilibrium in the ecosystem due to the biotic control of water nutrients, this situation drastically changed in mid-2015 when the resilient capacity of the ecosystems was overtaken. Today, there is talk of "environmental collapse", which has driven the ecosystem to several episodes of massive fish death.

This collapse has not only had a strong impact on the socio-economic sphere of the area, mainly due to a decrease in vacationers in the towns around the lagoon that are eminently touristic, but also has impacted other sectors such as fishing due to a lower availability of species of fishing interest [15]. These socio-economic effects have generated strong social concern. According to [22], even when university students' ideas about the impacts of this problem are explored, they tend to specify those of a socio-economic nature. Above all, those related to the reduction of employment and economic losses in the hotel and catering sector are pointed out, as well as others such as the devaluation of homes in the area. However, the ecological impacts are indicated with a lower level of precision, particularly in terms of pollution or threats to marine species.

To understand socio-ecological issues, the environmental factors often tend to be highlighted; therefore, the emphasis often lies on the consideration of the socio-economic impacts to be explicitly understood [23]. This is different in the problem of Mar Menor. Here, the emphasis should be oriented towards the identification of the events that occur in the ecosystem, which are less known than the socio-economic impacts.

Regarding the solutions proposed from the scientific and political sectors, they are aimed at different levels of the DPSIR (driver-pressures-state-impact-responses) schema for water stress [24]. Thus, the scientific community has proposed measures that address the first levels of the scheme, which aims to reduce the driving forces and their immediate effects (pressures) through more robust, long-lasting, and cost-effective measures [25]. Among these measures, strategies for good agricultural practices stand out, limiting the use of certain chemical fertilisers or establishing protection perimeters, as well as solutions based on the natural environment through the creation of a band of new wetland surfaces that act as green filters and intercept all flows. On the other hand, some political parties have also suggested solutions aimed to achieve the end of the above scheme, that is, measures aimed at addressing the impact, not its prevention. Among them, there was a proposal to expand the connection of Mar Menor with the Mediterranean Sea through dredging actions, aimed at facilitating the water renewal of the coastal lagoon.

Taking into account the set of debates and conflicts of interest around the problem and the strong interconnections between its ecological, social, and economic dimensions, it seems possible to accept the didactic interest of an educational approach. Such an approach should aim for students to recognise the causes and consequences, allowing for the assessment of different proposals for the solutions. To this end, it will be essential to identify what are the most important learning obstacles that appear when dealing with these types of issues at school.

2.2. Students' Conceptions and Difficulties in the Understanding of Socio-Ecological Problems

In order to involve children in environmental protection efforts from childhood, it is important to analyse their understanding of the socio-ecological problems [2], as the students' conceptions are crucial in determining what and how the topic must be taught in schools [26–28].

Some investigations defend children's ability "to understand relationships in the environment and effects of environmental change on nature" [2] (p. 2). At an early age, it seems that moral visions dominate, and the students are capable of making accurate (although simple) statements about environmental change [2,11]. Furthermore, Ref. [29] pointed out that children between 4 and 10 years old may be able to take a more long-term view of environmental issues and may make meaningful links between their causes and effects.

On the other hand, the study authored by [4] dealing with Finnish students' (aged between 10 and 11 years old) perceptions of water showed some interesting results. They concluded that students do not understand water's significant role in life, as water issues are not systematically considered in school and, instead, concentrated on subject-specific aspects. Therefore, these authors claimed for a more systemic and multidimensional discussion of water in the context of our life. This approach means integrating scientific, environmental, and even technological aspects into instruction, analysing them together with social points of view and decision-making.

In their study about the ocean literacy of older Portuguese and British students (12–14 years), Ref. [30] found that the students generally held low levels of knowledge about topics such as eutrophication. Even undergraduate students showed difficulties in the understanding of the complex interactions among the ecological and socio-economic factors leading the eutrophication process [31,32]. For [21,33], eutrophication represents a good example of a complex and dynamic process, which is therefore a very challenging issue. In order to understand the process, students are encouraged to cross system boundaries as well as seek explanations for the spatial variability and seasonal changes, as there are spatial and temporal patterns in the process that is under study. In addition, Ref. [34] reported students' difficulty to relate chemical production and biochemical processes on a micro scale to effects on a macro scale. In relation to this, younger children attributed the impact of certain environmental issues to what they could feel with their senses rather than to scientific implications [11]. Thus, recognising the causes linked to the input of nutrients into water and overcoming the concept that the causes of eutrophication are related to littering may be very challenging for students.

For all these reasons, in order to address this kind of complex socio-ecological problem, students need to display systemic thinking skills, which will allow them to recognise the interconnections between human activities and the changes produced in water bodies [35].

These difficulties may entail implications for students' perceptions of the urgency to act, support of given public policies, and awareness of the consequences of their own behaviour [30]. The authors of [36] warned that low levels of content knowledge, recognised as part of sustainability competences [7,37], may impede children from making informed decisions about the environment in the future. This aspect is crucial in the education for sustainability because if children's awareness "is not acted upon early, opportunities for protecting the environment in the future can go unnoticed" [11] (p. 20).

2.3. Educational Strategies to Address Socio-Ecological Problems

For these conceptions to progress, it is necessary that new knowledge obtained is related to the existing schemes, making students think for themselves based on relevant questions that they can answer [27]. This author considered socio-ecological problems as a good strategy to "give meaning and contextualise everyday and scientific knowledge in the process of building school knowledge" (p. 503). Therefore, it will be essential that the educational proposals to address these issues arise from real situations that increase interest, allowing students to relate environmental problems with their daily life [16] and observe the ways in which their actions can be influential [3,38].

Despite the above-mentioned study, Ref. [39] believes that "just the facts" teaching remains more common than "also the actions" approaches with respect to addressing socio-ecological problems. This approach leaves little room for young people's active participation and could represent "a missed opportunity to support children's awareness, agency, and action on a pivotal issue" [3] (p. 4).

Among the different strategies, problem-based learning (PBL) is considered an adequate approach for generating knowledge and meaning in relation to the circumstances in the local society and world [8] at any age. For [40] (p. 708), "learning this way [PBL] is helpful and motivating as the student learns while seeking solutions to problems based on real-life contexts. Students engage actively and learn in the context in which the knowledge will be used". To achieve this end, PBL applications provide information that students learn in order to solve a problem; therefore, the problem is presented at the beginning of the intervention. Consequently, this order is the reverse of traditional teaching methods, which only introduce problems after students have learned the necessary body of knowledge. For environmental issues, this is likely to require integrating methods from different scientific disciplines as well as the incorporation of information from non-science disciplines and the perspectives of multiple stakeholders. Thus, Ref. [41] proposed that PBL naturally leads to an increased interdisciplinary and holistic thinking.

For all of the above, it is of interest to design a problem that is related to the eutrophication of the Mar Menor coastal lagoon, one that deals with its causes, consequences, and possible solutions. This situation represents an extraordinary example in which various conflicts of interest linked to food production and distribution models are combined, as well as urban and tourist development that has occurred in recent decades.

3. Objectives

This work aimed to analyse how fifth and sixth grade primary school students recognise the key aspects of the problem, i.e., its causes, consequences, and solutions. Specifically, we asked the following questions:

- What interconnections do the students recognise between human activities and the eutrophication of the lagoon?
- How do they describe the eutrophication process?
- What solutions do they propose and how do they defend them?

Through these questions, we were interested in identifying how students manage to recognise the situation of Mar Menor in a holistic way. This could be useful for detecting possible difficulties in the understanding of the issue and establishing educational implications for its teaching.

4. Methodological Approach

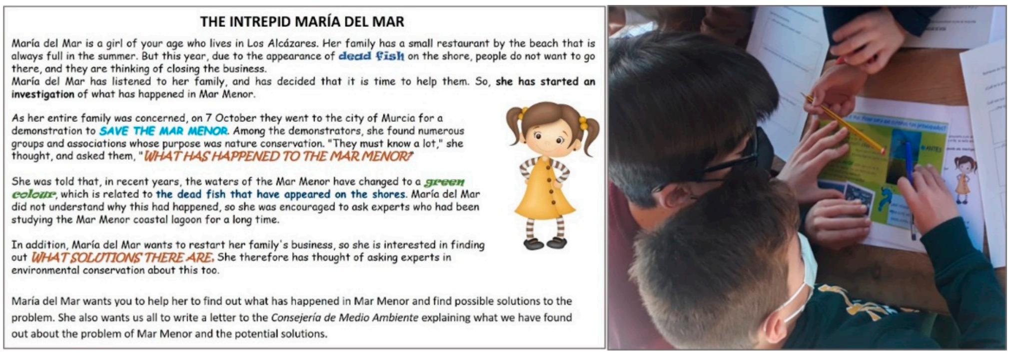
4.1. Participants and Educational Context

In this research, 224 students participated, specifically fifth and sixth graders -according to the Spanish system- aged between 10 and 12 years old (n = 98 and n = 126, respectively). All of them attended schools located in a city in the southeast of Spain, whose citizens have a strong link with Mar Menor. They were part of a previous study on students' ideas about the situation of Mar Menor, identifying what, basically, they referred to as aspects related to the presence of litter, in accordance with the available literature [11].

On this occasion, these students participated in an educational intervention on the problem of this lagoon. For this educational intervention, the problem of Mar Menor was approached from the socio-economic impacts (Table 1), which are widely recognised among the public [14]. The use of real problems set in familiar contexts for students is considered a key strategy for addressing the topic of sustainability in school [7,41]. From this context, students were invited to investigate what has happened in the area to reach the current situation in order to recognise the causes and consequences of the eutrophication process, as well as to identify possible solutions. To carry out this task, students were organised into small working groups of four members, in which no roles were previously distributed by the teacher. The teacher facilitated different sheets of information for the students, informed them about the tasks to be fulfilled, and supervised the development of the activity, prompting students to be as thorough in their responses as possible. The intervention, comprising a session of 2 h, was structured into four stages [32], which are described in Table 1.

Table 1. Description of the main objectives and tasks included in each stage of the intervention.

Stage	Educational Objectives	Tasks
I. Identification stage	- To explore and share their own ideas about the issue. - To identify key aspects of the problem.	The problem arises from an 11-year-old girl whose family runs a restaurant on the Mar Menor coast and, therefore, has been affected by the problem (Figure 1). The girl introduces the key questions and asks the participants to look for responses.
II. Investigation stage	- To recognise the interference of agricultural activities in the marine ecosystem. - To identify key steps in the eutrophication process. - To analyse different solutions in a comparative way. - To promote a systems thinking approach when addressing the problem.	In this phase, the groups of students work autonomously, using the information obtained by the protagonist when she asks several experts and stakeholders, organised into different materials (sheets of information, specially designed by the teacher). The organisation of the materials is based on the key issues identified (in terms of causes and consequences) and includes an assessment of the main solutions proposed from the scientific and political spheres.
III. Conclusion stage	- To draw conclusions regarding the problem about why the water is green, its relationship with the appearance of dead fish, and the most efficient solution.	The students complete the report sheet, where they record their conclusions on the key questions.
IV. Action stage	- To value the importance of citizen action. - To request actions from the competent body to deal with the problem.	The students discuss possible actions to demand responsibilities from the competent authority. Finally, they write individual letters to such administrative agents proposing and justifying a solution. The set of letters has been officially sent to the competent authority.



THE INTREPID MARÍA DEL MAR

María del Mar is a girl of your age who lives in Los Alcázares. Her family has a small restaurant by the beach that is always full in the summer. But this year, due to the appearance of dead fish on the shore, people do not want to go there, and they are thinking of closing the business.
María del Mar has listened to her family, and has decided that it is time to help them. So, **she has started an investigation** of what has happened in Mar Menor.

As her entire family was concerned, on 7 October they went to the city of Murcia for a demonstration to SAVE THE MAR MENOR. Among the demonstrators, she found numerous groups and associations whose purpose was nature conservation. "They must know a lot," she thought, and asked them, "WHAT HAS HAPPENED TO THE MAR MENOR?"

She was told that, in recent years, the waters of the Mar Menor have changed to a green colour, which is related to the dead fish that have appeared on the shores. María del Mar did not understand why this had happened, so she was encouraged to ask experts who had been studying the Mar Menor coastal lagoon for a long time.

In addition, María del Mar wants to restart her family's business, so she is interested in finding out WHAT SOLUTIONS THERE ARE. She therefore has thought of asking experts in environmental conservation about this too.

María del Mar wants you to help her to find out what has happened in Mar Menor and find possible solutions to the problem. She also wants us all to write a letter to the *Consejería de Medio Ambiente* explaining what we have found out about the problem of Mar Menor and the potential solutions.

Figure 1. Statement of the problem (**left**); sixth grade students working on the activity (**right**).

4.2. Data Collection

Two instruments were used for the data collection in this research. Although the students were organised into working groups, both instruments were completed individually:

- A report sheet, which was completed during the Conclusion stage. It was composed of two questions: "Why has the water turned green?" and "How would you explain the fish deaths?". Therefore, this report allowed us to analyse the causes and consequences that students associated with the problem;
- A personal letter, completed during the Action stage. Starting from the initial heading, "Dear person in charge of the Regional Ministry of Environment", it was proposed that each student prepare their own dissertation on what solution they considered most appropriate, including a justification for the solution.

Before the intervention, a pilot study was carried out with 10 students, enrolled in the same grades as the participants, in order to be sure that they understood the questions as well as the information provided by the teacher. The final version of the intervention included the suggestions of these students from the pilot study.

4.3. Data Analysis

The methodological framework used for data analysis was a qualitative content analysis approach [42,43]. For [43] (p. 120), qualitative content analysis (QCA) can be understood as "the process of categorising qualitative textual data into clusters of similar entities, or conceptual categories, to identify consistent patterns and relationships between variables or themes". In this work, the significant units of information for each aspect (causes, consequences, and solutions) were selected, examined, and deductively categorised, as described in the following sections.

4.3.1. Causes

For the analysis of the causes, we valued the causal connections established by the participants between the agricultural development of the surrounding area and the perceivable events in the lagoon, specifically, the change in the colour of its water. The interest of this resides in the recognition of interconnections between specific human activities (which take place outside the lagoon) and the changes that occur in the lagoon. Based on [32], three categories were established:

- Complete interconnections: when the agricultural development of the area was recognised as an activity that generates changes in the lagoon;
- Incomplete interconnections: when relations were established between fertilisers and algal growth, but did not make explicit reference to the agricultural development of the area;
- Inadequate interconnections: when adequate relationships regarding the origin of the problem were not established.

4.3.2. Consequences

Regarding the consequences, the analysis focused on the identification of the eutrophication process which was structured into four key phases [33]: (i) the microalgae proliferate acting as a barrier and making it difficult for sunlight to reach the seabed; (ii) the benthic plants and algae, which cannot photosynthesise; (iii) less oxygen present in the water; and (iv) living beings dying from a lack of oxygen. This allowed for the identification of three categories:

- Pupils that recognised the eutrophication process as a whole (pointing out all key stages), who were included in category 1;
- Those who missed any of these key stages, who were included in category 2;
- Those who referred to aspects other than the process, without identifying any of its key stages, who were included in category 3;

Thus, it was possible to detect where the students' difficulties lay in understanding the eutrophication process.

4.3.3. Solutions

In the analysis of the solutions, on the one hand we looked at their relationship with respect to the causes of the problem [25]; that is, we observed whether the solutions acted on the drivers and pressures or on the impact. On the other hand, we looked at the level of sophistication in the students' answers; specifically, we examined if they were able to use evidence in the form of data and justifications to defend their proposal [44,45]. Thus, four categories were established:

- When students did not use any evidence to justify their selected solution;
- When students mentioned some of the advantages of their selected solution;
- When students included not only advantages but also disadvantages of their selected solution;
- When students performed a comparative analysis, contrasting the advantages and disadvantages of different solutions (not only about the selected one).

4.3.4. Understanding of the Problem

To recognise the understanding that students obtained regarding the problem, the relationship between the three variables was estimated through a correlation analysis, while the report sheets and written letters were analysed within the methodological framework of a qualitative content analysis [42]. According to [43], this analysis process allows for the identification of consistent relationships between variables. The significant information units identified for each variable were conjointly examined to inductively group them into models. To establish the models as definitive, they were reviewed and contrasted in several analysis cycles by two of the researchers involved. As a result of this process, a total of five models were established, which represented the accuracy of the students' understanding of the problem as a whole as well as their use of evidence when justifying the selected solution. In this sense, Model 1 groups the students that showed significant difficulties in recognising the causes and consequences of the problem and who were unable to propose solutions. At the other extreme, Model 5 encompasses students who recognised the key role of agricultural activity and fully described the phases of the eutrophication process; at the same time, they were able to justify accurate solutions with a high level of sophistication (using evidence and contrasting the advantages and disadvantages of each solution, performing a type of comparative analysis).

The interrater Cohen's kappa coefficients were calculated by examining the percent accordance of the raters' categorisation of the data input. The Cohen's kappa score was 0.89, indicating a strong agreement between the raters [46].

In the three variables and established models, descriptive statistics were calculated in the form of frequencies. In addition, to recognise possible differences between the fifth and sixth grade students, the non-parametric Mann–Whitney *U* test was applied. All statistical analyses were performed using the SPSS v.28.0 statistical package, with a 95% confidence interval.

5. Results

5.1. Causes

When students evaluated the causes of colour change in the waters, the majority (n = 158) was able to establish adequate interconnections with the agricultural activity of the area (Table 2). Specifically, they referred to the fact that the arrival of fertilisers from the intense agricultural activity in the area favours an algal bloom on the surface, which gives a green colour to the water. Two-thirds of the students who made these interconnections belonged to the sixth grade, such as student 114 (P.114), who said: "*In the fields, the water with fertiliser is used for irrigating and this water ends up in the sea, loaded with nutrients, which is why algae grow faster than normal on the surface, forming a green mantle*".

Another 36 students related the proliferation of the algae to fertilisers, but without explicit reference to the agricultural development of the area. For this reason, the interconnections they established were considered incomplete, such as the following excerpt: "*The fertilisers that reach the sea cause microscopic algae to grow and that makes a green mantle in the water*" (P.20).

Table 2. The frequency and percentage of responses regarding the identification of the causes in both grades.

Recognition of Interconnections	Total (%)	Grade (%)		Difference in 5th–6th Grades
		5th	6th	
Complete interconnections	158 (70.54)	59 (37.3)	99 (62.7)	Z = −2.963; p = 0.003
Incomplete interconnections	36 (16.08)	21 (58.3)	15 (41.7)	
Inadequate interconnections	30 (13.4)	18 (60.0)	12 (40.0)	
Total	224	98	126	

With a similar frequency (n = 30), some students were unable to make adequate interconnections. They recognised human activity as the origin of the problem, but they maintained that the arrival of litter or algae being dragged into the lagoon were responsible; thus, the green colour of the waters would be directly generated by the discharges that arrive. The highest percentage of students who made inadequate interconnections belonged to the fifth grade.

When assessing the differences between both grades, statistically significant differences were found (Z = −2.963; p = 0.003), where the sixth grade students more frequently recognised complete interconnections between the crops and changes in the ecosystem.

5.2. Consequences

When trying to explain the fish mortality, two large groups of students were observed (Table 3). On the one hand, we found those that offered full descriptions of the eutrophication process, pointing out the four key stages (n = 95). Just over half of this group was made up of sixth graders.

With a slightly higher frequency (n = 104), the other group included students who offered incomplete explanations by skipping some stage of the eutrophication process. Frequently, these were the intermediate stages, so they did not indicate the effect on the photosynthesis process or did not explicitly relate it to the presence of oxygen in the water column, such as the following excerpt: "*The green mantle prevents light from reaching the bottom and oxygen from being produced and the fish end up dying*" (P.63). Nearly two-thirds of these students were in the sixth grade (Figure 2).

Table 3. The frequency and percentage of responses regarding the description of the eutrophication process in both grades.

Description of the Eutrophication Process	Total (%)	Grade (%)		Difference in 5th–6th Grades
		5th	6th	
Category 1: They referred to the process, pointing out its key stages	95 (42.41)	41 (43.2)	54 (56.8)	Z= −1.115; p = 0.265
Category 2: They referred to the process, omitting a key stage	104 (46.43)	40 (38.5)	64 (61.5)	
Category 3: They referred to different aspects of the process	25 (11.16)	17 (68.0)	8 (32.0)	
Total	224	98	126	

Some students did not refer to the eutrophication (n = 25), offering generic explanations, such as the following: "*The fertilisers pollute the water and then the fish die*" (P.40). A large portion of these students belonged to the fifth grade.

When comparing both grades, although a certain tendency was observed for sixth graders for more precisely describing the eutrophication process, these differences were not significant (Z = −1.115; p = 0.265).

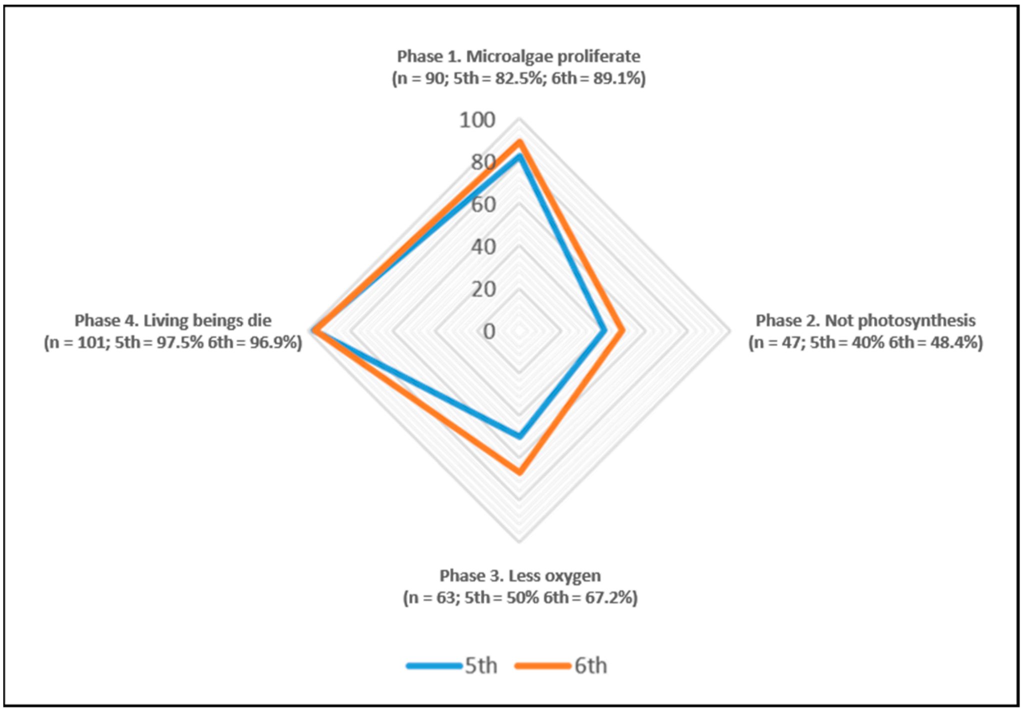


Figure 2. Distribution of students included in category 2 regarding the description of the eutrophication process.

5.3. Solutions

In the proposal of solutions, the vast majority of students (n = 173) offered solutions related to the main causes and were aimed at reducing the driving forces and pressures (Table 4); these solutions were differentiated into three groups:

- Almost half of the students (n = 80) proposed the implementation of a green belt of wetlands in order to reduce the amount of fertiliser in the water before it reaches the sea (pressures). More than two-thirds of these students belonged to the sixth grade;
- Another group (n = 58) focused on agricultural management (driving forces). Mainly, they pointed out limiting the use of fertilisers to prevent the contamination of the lagoon. Exceptional cases (n = 3), proposed to declare a band without crops in the area closest to it. Most of this group belonged to the fifth grade;
- Another 35 students, mostly from the sixth grade, combined both solutions.

Delving deeper into how these students defended their decision, we observed that up to 69 students, although proposing some solution related to the main causes, did not use any evidence to support their choice (Figure 3). Mainly belonging to the sixth grade, the students simply indicated that it was the best solution without justifying or using data managed during the investigation stage.

However, most students (n = 104) offered justifications with different levels of sophistication:

- More than half (n = 65) emphasised the advantages of the chosen solution. In the case of student 116: "*The wetland belt is the best option because it is 100% natural, it only needs sunlight, and nobody would be left without work*". These students belonged to the fifth and sixth grade in similar proportions;
- Another 23 students indicated the advantage of their solution, but also pointed out certain disadvantages, such as in the case of P.91: "*To save Mar Menor, my proposal is to limit the use of fertilisers in the fields. This has advantages because it is the most direct way to reduce its negative effects, but also disadvantages because it could mean losses for agriculture,*

as crops do not grow as fast". This group also presented a similar proportion of fifth and sixth graders;

- Another 16 students opted for a solution after a comparative analysis of the advantages and disadvantages of various solutions. This is the case of student 128, who stated: "*The best proposal is to use wetlands, which are a kind of natural filter that absorbs chemicals and thus their plants grow. Please don't connect Mar Menor and the Mediterranean Sea because you need very destructive machinery and you would end up polluting both*". Except for a single fifth grader, the rest of this group belonged to the sixth grade.

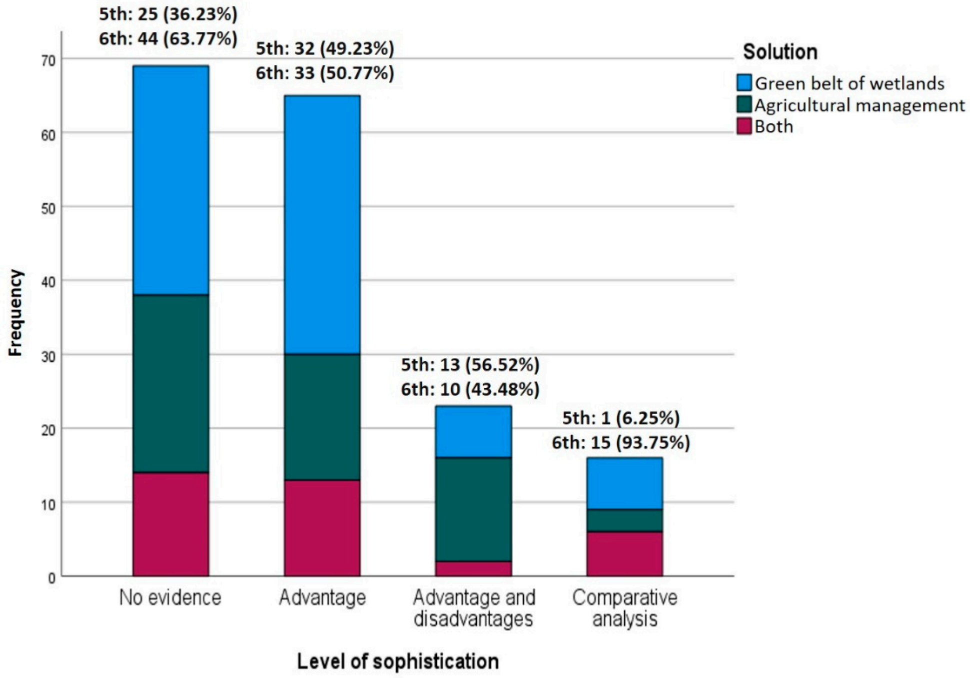


Figure 3. Level of sophistication of the students' answers in proposing solutions related to the causes.

Another 47 students proposed a solution unrelated to the main causes. Their proposals were aimed at monitoring the environment, to avoid the presence of litter, or to control bathing and fishing. In this group, there was a similar proportion of fifth and sixth graders. Their answers tended to have a low level of sophistication as they did not use evidence. They referred to vague aspects such as the interest to protect the lagoon as, for example: "*It is necessary to have more police officers to protect the Mar Menor, and also to put more litter bins and to clean it every day or almost every day*" (P.3).

Only four students suggested measures aimed at addressing the impact, not its prevention, such as the expansion of the connections between Mar Menor and the Mediterranean Sea, for a greater entry of water from the latter. They offered justifications based on the fact that, in this way, it is possible to mitigate the impacts suffered by the lagoon and maintain agricultural activities, given their relevance in the area. Finally, another four students did not provide any solution, but again focused on the causes; almost all of them belonged to the fifth grade.

Considering the proposed solutions on a global scale, there was a tendency for sixth grade students to opt for wetlands compared with fifth graders, who would prefer agricultural planning. However, these differences were not statistically significant ($Z = -0.813$, $p = 0.416$). Regarding the level of sophistication in their answers in consideration of the total group of students, there was no significance either ($Z = -1.818$, $p = 0.069$). However, within the specific set of students that offered solutions aimed at correction or prevention—which included the vast majority of students—sixth grade students suggested more sophisticated approaches ($Z = -2.930$, $p = 0.003$).

Table 4. The frequency and percentage of responses regarding the solutions in both grades.

Solution Proposal		Total (%)	Grade (%)		Difference in 5th–6th Grades
			5th	6th	
Related to the causes, aimed at prevention	Green belt of wetlands	80 (35.71)	26 (32.5)	54 (67.5)	Z = −0.813; p = 0.416
	Agricultural planning	58 (25.89)	39 (67.24)	19 (32.76)	
	Agricultural planning and green belt of wetlands	35 (15.63)	6 (17.14)	29 (85.86)	
	Total	173 (77.23)	71 (41.04)	102 (58.96)	
Unrelated to the causes, aimed at monitoring the environment in general	Beach cleaning	18 (8.04)	8 (44.44)	10 (55.56)	
	Swim control	11 (4.91)	6 (54.55)	5 (45.45)	
	Fishing control	9 (4.02)	4 (44.44)	5 (55.56)	
	Increased surveillance in the area	6 (2.68)	4 (66.67)	2 (33.33)	
	Other	3 (1.34)	2 (66.67)	1 (33.33)	
	Total	47 (20.98)	24 (51.06)	23 (48.94)	
Related to the impacts	Greater connections between Mar Menor and the Mediterranean Sea	4 (1.79)	3 (75.0)	1 (25.0)	
No solutions proposed		4 (1.79)	3 (75.0)	1 (25.0)	
Total		224	98	126	

5.4. Understanding of the Problem

When assessing the correlation between the identification of the causes, consequences, and solutions, a certain positive relationship was observed between the three variables in all cases. In other words, this occurred when considering the total number of participants and when differentiating by grade. This indicates that a good identification of one of the key aspects of the problem would be related to a better identification of the other two and, therefore, a greater understanding of the problem (Table 5).

Table 5. Correlations between the key aspects of the problem.

Correlation	Total	Grade	
		5th	6th
Causes–Consequences	$\rho = 0.585$ $p < 0.001$	$\rho = 0.616$ $p < 0.001$	$\rho = 0.534$ $p < 0.001$
Causes–Solutions	$\rho = 0.431$ $p < 0.001$	$\rho = 0.435$ $p = 0.02$	$\rho = 0.392$ $p = 0.032$
Consequences–Solutions	$\rho = 0.607$ $p < 0.001$	$\rho = 0.664$ $p < 0.001$	$\rho = 0.581$ $p < 0.001$

However, it is notable that the weakest relationships were detected between the causes and the solutions. On the contrary, the strongest correlations were observed between the consequences and the solutions. This may respond to the certain dominance of solutions that responded to pressures rather than responding to the driving forces that generated them; this demonstrated that there was a certain reluctance to control agricultural activity.

In order to further analyse the understanding that students reached regarding the problem as a whole, a total of five models have been established (Table 6):

- Model 1 encompasses the students who presented significant difficulties in recognising the causes and consequences of the problem and were also unable to propose solutions (n = 21). They did not recognise any clear interconnections between agricultural activity and the eutrophication process, and whose stages were not identified or only partially identified. Regarding the solutions, they focused on the importance of conserving Mar Menor and keeping it clean. Therefore, they tended to propose measures outside the main causes and used a minimum level of sophistication in the use of evidence. Most of them were fifth graders, although only around 15% of the students within this grade were included in this model;
- Model 2 covers the students who did not adequately identify the causes and consequences of the problem. Thus, they failed to recognise the key role of agricultural activity and presented difficulties in fully describing the eutrophication process. However, these students did manage to propose adequate solutions, mostly opting for the implementation of a green belt of wetlands. Moreover, the level of sophistication of their answers was high, using different evidence to justify the advantages of their proposal. For example, they indicated that wetlands were a solution that favoured the presence of protected birds and did not produce dangerous sludge. Some of this group even included comparisons between solutions; for example, they presented some of the advantages of wetlands, emphasising at the same time that expanding connections with the Mediterranean Sea would mean losing the ecological value of Mar Menor. Therefore, this model represents students with a conservationist but naïve view of the problem. Its frequency was quite low, with a certain dominance of fifth graders;
- Model 3 includes students who were able to identify the causes and consequences of the problem but were unable to defend the adjusted solutions. Thus, they considered the entry of nutrients to the lagoon from agricultural fields and recognised the resulting eutrophication process. However, when proposing solutions, they either did not specify the rationale, or their solutions presented a low level of sophistication, as they did not use data or justifications; they simply indicated that their option was the most suitable or, in certain cases, referred to the need to monitor the environment, in general terms. Around a fifth of the participants were represented this model, with a slightly higher proportion belonging to the sixth grade. Among them, there might be difficulties in recognising suitable solutions, although it is also possible that such difficulties lie in their ability to use evidence. Alternatively, in simple terms, they have avoided the use of evidence when writing their letters;
- Model 4 comprises students who recognised, without apparent difficulties, the interconnections between agricultural activity and the consequences, managing to adequately describe the eutrophication process. In addition, they proposed adjusted solutions that were focused both on the implementation of the green belt of wetlands and on agricultural planning, or the combination of both strategies. In general, their answers presented a good level of sophistication and emphasised the advantages of the solution they proposed. Some students even went further and also evaluated certain disadvantages of the strategy. This model, which represents a complete understanding of the problem as a whole, represented more than half of the participants, with only a slightly higher proportion of sixth graders;
- Model 5 encompasses students who, in addition to recognising the key role of agricultural activity and fully describing the phases of the eutrophication process, defended the adjusted solutions with a high level of sophistication. In all cases, they proposed the green belt of wetlands, and only some of them combined it with the limitation of the use of chemical fertilisers. When evaluating these solutions, they carried out a comparative analysis, contrasting the advantages and disadvantages of each solution,

on which they based their proposal. Above all, they refuted the expansion of the connections between the lagoon and the Mediterranean Sea, given that it does not address the impacts, but rather means making the problem chronic. This model was presented by 14 students who were mostly from the sixth grade.

Table 6. The frequency and percentage regarding the models in both grades.

Models	Total (%)	Grade (% per Grade)		Difference in 5th–6th Grades
		5th	6th	
Model 1. No key aspect was identified	21 (9.4)	15 (71.4)	6 (28.6)	Z: −2.831; p = 0.005
Model 2. Only potential solutions were identified	8 (3.6)	5 (62.5)	3 (37.5)	
Model 3. Causes and consequences were identified, but no evidence-based solutions were proposed	51 (22.8)	21 (41.2)	27 (58.8)	
Model 4. Causes and consequences were identified, and evidence-based solutions were proposed	130 (58.0)	56 (43.1)	77 (56.9)	
Model 5. Causes and consequences were identified, and evidence-based solutions were proposed, with a high level of sophistication	14 (6.3)	1 (7.1)	13 (92.9)	
Total	224	98	126	

When assessing the differences in the models presented by the students according to their grade, there was a statistical significance observed (Z: −2.831; p = 0.005). The results indicate that, although the participants generally reached an adequate understanding of the problem, the sixth graders presented greater facilities for constructing the solutions, especially notable in the use of evidence to defend their solution proposals.

6. Discussion and Educational Implications

The present work delved into how students of the fifth and sixth grades of primary school recognise the key aspects of the eutrophication problem with respect to waters, i.e., its causes, consequences, and solutions, as well as the understanding that they reached on the entire subject. For this, an educational proposal based on the use of problems was designed, using the eutrophication scenario of Mar Menor lagoon, given the proximity and relevance to the participants' environment [16,40]. In addition, the framework allowed for the introduction of the scientific concept of eutrophication as a dynamic and complex process that explains the connections between causes and consequences, promoting the students' involvement in real-world problems [2,21,41].

When assessing how they identified the causes, it was observed that majority of the participants were able to establish interconnections between human activities which take place in the surroundings of the lagoon, and the changes in the lagoon. Specifically, with different levels of precision, they recognised how agricultural development was primarily responsible for the green colour of water. Therefore, they appeared to go beyond the idea that intensive agriculture is merely an innocuous practice and is even favourable for the natural environment [31].

In addition, these interconnections helped the students approach a more complex vision of the problem by not limiting the cause to only the perceivable events that occurred in the lagoon or on its shores [11], such as the presence of litter. Thus, they seemed to achieve a base-level reading, contributing to the development of systemic thinking skills and critical thinking, which are essential for an adequate understanding of socio-ecological problems [8].

However, it is important to note that establishing these interconnections was more challenging for fifth graders than for sixth graders. More precisely, these statistical differences could derive from greater difficulties in overcoming a simple perspective of the process; they must recognise the relationships at more complex spatial-temporal scales, in which they must understand that there are certain delays between the causes and the appearance of the consequences as well as the micro and macro levels involved in the process [21]. Therefore, for this grade, it could be interesting to include educational strategies that reduce the necessary level of abstraction, visually reinforcing the interconnections between the crops and the lagoon. A useful didactic resource for this could be the use of mock-ups that represent the lagoon and its surroundings. Different investigations point to the fact that the use of these types of models favours the understanding of the dynamic processes related to water, especially those that are not visible [47].

Thus, when the students attempted to explain the eutrophication process, the main difficulties in both grades were observed in the identification of the intermediate and more abstract stages. That is, one which involves the micro scale that is related to the chemistry of water and explains the presence of oxygen and its variations [41]. On the other hand, associated with the lack of oxygen, due to the difficulties for photosynthesis in the environment, the fish mortality was more evident to the students. This may be due to the analogical representations that they created, which were mediated by the experiences of the students about the role of this element in our lives [48].

Despite these difficulties in identifying the complete eutrophication process, this work suggests that bringing students closer to the ecosystem events that are implied would help them to propose measures aimed at limiting the entry of nutrients to the lagoon. Therefore, instead of attending to the impact, most students opted for measures aimed at its prevention. Delving into this result, a certain dominance of nature-based solutions was observed through the implementation of a green belt of wetlands, especially in sixth grade. Thus, within these prevention measures, there was a tendency to act on the pressures, rather than limiting the intensive agriculture as a driving force. In addition, when they opted for agricultural planning, the students presented a higher level of sophistication in their answers. In this sense, along with the advantages, these students mentioned the disadvantages in a higher proportion, referring to their negative socio-economic impacts.

Although more in-depth studies would be necessary, from what has been said above, it seems that the solution proposal made by students could be strongly mediated by the socio-cultural context of the area. Different studies have highlighted this context as a key external factor in human behaviours in response to socio-ecological problems [49,50]. Specifically, it appears that the social perceptions regarding the agriculture in relation to the high value of this activity for the relevant socio-economic fabric of the area strongly influenced the solutions proposed by these students [14]. Thus, the students maintained some reluctance for limiting the agricultural development in the area around the lagoon. Considering this, it may be of interest to promote this discussion in the classroom through strategies that emphasise the conflicts of interest of this problem: for example, between tourism and agriculture, for the purpose of developing the student's critical thinking [6].

Finally, by assessing the understanding of the problem, this work provides the identification of five models according to how the students jointly identified their causes, consequences, and solutions. Recognising how children understand the problems of eutrophication can help detect their difficulties in the subject and guide how to teach the topic [27]. In this sense, it has been observed that a third of the participants showed some difficulties, especially linked to the use of a higher level of sophistication when defending the proposed solutions. However, more than half of the participants were at level 4, as they were able to recognise the interconnections between agricultural activity and the problem and were able to sufficiently describe the eutrophication process. In addition, they proposed adjusted solutions aimed at prevention and emphasised the advantages of the solution that they proposed; some even went further and also evaluated certain disadvantages of the plan.

According to the analysis of these levels, it seems that the strategy of using real and near problems may be considered effective in improving children's environmental awareness and knowledge, as well as fostering positive attitudes towards the natural environment [51]. However, we must accept the limitations that prevent us from generalising these results. These are related to the restriction of the number of participants and the duration of the proposal itself. This short intervention may be insufficient for producing meaningful and long-lasting change regarding the complex socio-ecological issues and actions. Moreover, although a short pilot study was carried out, there was not a complete validity of the instruments used for data collection. Future educational interventions should be extended to analyse these potential long-lasting changes in order to overcome some of the difficulties detected among certain groups of children, especially those of a younger age.

Even with these limitations, this research can be useful for future educational research and can be adapted to the local situation, as eutrophication problems linked to agricultural intensification are recurrent in many parts of the world. The identified models could be useful for designing meaningful learning experiences aimed at promoting active environmental concerns about these problems at an early age [52]. The models may also be suitable for analysing the effectiveness of new educational experiences that address these eutrophication problems, capable of assessing the learning progression of children about this particular topic [53].

The importance of advancement in this field responds to the need to empower children in the face of environmental issues in their environment, offering them opportunities for active participation in the search for solutions; this is conducted so that they are recognised as agents of change [10,13]. Consequently, it is possible to contribute to their acquisition of knowledge and help them attain the skills needed to promote long-term sustainability [54].

Author Contributions: Conceptualization, I.B.-G. and P.E.-G.; methodology, I.B.-G., A.R.-N. and P.E.-G.; validation, M.V.-P., A.R.-N. and P.E.-G.; formal analysis, I.B.-G.; investigation, I.B.-G., M.V.-P., A.R.-N. and P.E.-G.; data curation, I.B.-G., M.V.-P. and P.E.-G.; writing—original draft preparation, I.B.-G. and P.E.-G.; writing—review and editing, M.V.-P. and A.R.-N.; visualization, I.B.-G. and P.E.-G.; supervision, I.B.-G., M.V.-P., A.R.-N. and P.E.-G.; project administration, I.B.-G.; funding acquisition, I.B.-G. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by AGENCIA ESTATAL DE INVESTIGACIÓN (Ministerio de Ciencia e Innovación, Gobierno de España), grant number PID2019-105705RA-I00/AEI/10.13039/501100011033 and The APC was funded by PID2019-105705RA-I00/AEI/10.13039/501100011033.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by Ethics Committee of the University of Murcia (protocol code 2526/2019, 15 November 2019).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Not applicable.

Acknowledgments: We acknowledge the help of the teachers and students who participated in this study. This study is also a part of a major Innovation Project of the University of Murcia (ID 5887).

Conflicts of Interest: The authors declare no conflict of interest.

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