Assessing Water Quality and Future Kindergarten Teachers' Perceptions in a Freshwater Ecosystem: A Multifaceted Study

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Abstract: *This comprehensive study investigates water quality in a freshwater ecosystem through the lens of chemical analysis, sensory perceptions, and student awareness. Three distinct facets of the research are explored: (1) the physicochemical parameters of water quality, (2) student perceptions and understanding of water quality concepts, and (3) the convergence or divergence of these perspectives. Water samples were collected from various locations within the lake Pamvotis, and a series of workshops involving 160 undergraduates in Early Childhood Education were conducted. Each workshop incorporated measurements of key parameters (pH, Ammonium, Total Hardness, Phosphates, Nitrites and Nitrates) alongside sensory observations (odor, color, taste, turbidity). Additionally, participants answered a series of questions to gauge their knowledge of water quality concepts. Chemical analysis revealed spatial variability in lake water quality, with differences in the key parameters across sampling points. Drinking water consistently exhibited lower levels of these parameters. Student responses to the Mentimeter poll highlighted a mix of accurate and misconceived perceptions, with notable gaps in understanding, particularly regarding the causes of eutrophication, nitrate/nitrite impacts, and the sources of phosphates in lake water. This multifaceted study emphasizes the importance of considering both objective chemical analysis and student perceptions in assessing water quality in freshwater ecosystems. While chemical parameters provide quantifiable data, student perceptions underscore the need for improved environmental education. The research findings offer insights into potential areas for education and outreach efforts, as well as opportunities for further investigation into the complex interactions between science education and environmental awareness.*

Keywords: *Water Quality Assessment, Freshwater Ecosystem, Student perceptions, Environmental Education, Chemical Analysis*

Αξιολόγηση της Ποιότητας του Νερού και των Αντιλήψεων Μελλοντικών Νηπιαγωγών στη λίμνη Παμβώτιδα: Μια πολυδιάστατη Μελέτη

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Περίληψη: *Η σφαιρική αυτή μελέτη διερευνά την ποιότητα του νερού σε ένα λιμναίο οικοσύστημα μέσα από το πρίσμα της χημικής ανάλυσης, των αισθήσεων και της ευαισθητοποίησης των φοιτητών. Εξετάζονται τρία διακριτά κομμάτια της έρευνας: (1) οι φυσικοχημικές παράμετροι της ποιότητας του νερού, (2) οι αντιλήψεις και η κατανόηση των μελλοντικών νηπιαγωγών σχετικά με τις έννοιες της ποιότητας του νερού και (3) η σύγκλιση ή*

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απόκλιση αυτών των απόψεων. Τη δειγματοληψία νερού από διαφορετικές τοποθεσίες της λίμνης Παμβώτιδας διαδέχτηκαν εργαστηριακά μαθήματα με τη συμμετοχή 160 προπτυχιακών φοιτητών Προσχολικής Εκπαίδευσης που περιλάμβαναν ερωτήσεις αξιολόγησης γνώσεων σχετικά με την ποιότητα του νερού, αισθητηριακές αξιολογήσεις (οσμή, χρώμα, γεύση, θολότητα) και χημική ανάλυση σε φυσικοχημικές παραμέτρους (pH, Αμμωνία, Συνολική Σκληρότητα, Φωσφορικά, Νιτρώδη και Νιτρικά). Οι απαντήσεις των φοιτητών στο Mentimeter αποκάλυψαν μία μίξη ακριβών και λανθασμένων αντιλήψεων, ιδίως όσον αφορά τα αίτια του ευτροφισμού, τις επιπτώσεις των νιτρωδών και νιτρικών, και τις πηγές των φωσφορικών στο νερό της λίμνης. Η χημική ανάλυση απέδειξε χωρική μεταβλητότητα στην ποιότητα του νερού της λίμνης, με διαφορές στα επίπεδα των βασικών παραμέτρων σε διάφορα σημεία λήψης δειγμάτων Η παρούσα έρευνα υπογραμμίζει τη σημασία της συνυπολογιστικής ανάλυσης τόσο των αντικειμενικών χημικών μετρήσεων όσο και των αντιλήψεων των φοιτητών στην αξιολόγηση της ποιότητας του νερού σε λιμναία οικοσυστήματα. Ενώ οι χημικές μετρήσεις παρέχουν ποσοτικά δεδομένα, οι αντιλήψεις των φοιτητών υπογραμμίζουν την ανάγκη βελτίωσης της περιβαλλοντικής εκπαίδευσης. Τα ευρήματα της έρευνας προσφέρουν εισηγήσεις για πεδία δυνητικής εκπαίδευσης και ενημέρωσης, καθώς και ευκαιρίες για περαιτέρω έρευνα σχετικά με τις πολύπλοκες αλληλεπιδράσεις μεταξύ της εκπαίδευσης στις επιστήμες και της περιβαλλοντικής ευαισθητοποίησης.

Λέξεις κλειδιά: *Αξιολόγηση Ποιότητας Νερού, Λιμναίο Οικοσύστημα, Αντιλήψεις Φοιτητών, Περιβαλλοντική Εκπαίδευση, Χημική Ανάλυση*

Introduction

The concern on the effects of anthropogenic pollution of freshwater ecosystems and the continuous degradation of natural environment is growing. Lake Pamvotis (NW Greece) is a shallow typical Mediterranean ecosystem of great importance regarding biodiversity and to aesthetic value, influenced by many anthropogenic influences such as sewage discharge and water level fluctuations, during the recent decades (Kagalou et al., 2001) The lake has great recreational value and it also supports local agriculture, tourism, and fisheries. Lake Pamvotis is a eutrophic ecosystem which has been influenced by the nutrients input, rates of nutrient cycling and plankton-fish dynamics. (Kagalou et al., 2001). Moreover, effluents from animal farms containing fertilizers and pesticides reach the lake, enhancing the lake's contamination burden.

Freshwater pesticide contamination has become a major environmental problem in recent decades, raising concerns about risks to freshwater ecosystems (Schäfer et al., 2011). The presence of numerous pesticides in surface water as well as sediment is well documented worldwide. Reported concentrations in water are highly variable, with the highest concentrations found in small rivers draining dense farmland immediately after application, but longer concentration peaks in larger systems. Pesticide residues can enter surface waters primarily through agricultural runoff. Both parent pesticides and metabolites can exert toxic effects on organisms inhabiting various compartments of freshwater systems when the concentrations of the compounds are sufficient to induce such effects. The complexity of aquatic ecosystems and the interdependence of many species in food webs means that disruption of even small parts of the system can lead to secondary or indirect effects due to the toxic effects of pollutants. Protecting certain ecosystems, such as surface waters, requires preserving their ecological functions.

To promote and achieve sustainable development, environmental education has been assigned a key role. Environmental education promotes the active participation of citizens in environmental, social and economic challenges, enables every person to acquire the knowledge, skills, attitudes and values necessary for shaping a sustainable future, allows individuals and communities to reflect on ways of interpreting and engaging with the world, is future-oriented, focusing on protecting the environment as well as creating a more ecologically and socially just world through informed action and promotes skills such as critical thinking, imagining future scenarios and making decisions in a collective way (Leicht, 2018). By assessing the impact of the program, we hope to gain insights into the state of environmental education and its potential to shape future resource users who are equipped to protect and preserve freshwater ecosystems.

To achieve our aim, we have formulated the following research question:

"How do scientific measurements and sensory perceptions align in assessing water quality in Lake Pamvotis and drinkable water?"

The research objectives for answering the above question are facilitated by three subquestions:

What are the scientific measurements (Ph, Ammonium, Phosphates, Total Hardness, Nitrites, Nitrates) that define water quality in Lake Pamvotis?

How do sensory perceptions (odor, color, taste, turbidity) of water quality in Lake Pamvotis compare with scientific measurements and student assessments?

To what extent do student assessments align with scientific measurements when assessing water quality in Lake Pamvotis?

Through this study, we aim to shed light on the complex interactions between science education and environmental awareness while identifying areas for education and outreach efforts.

Study Area

Lake Pamvotis (the nurturer of everything) is one of the largest lakes in NW Greece (Long: 20.886888, Lat: 39.665074) occupying 22m^2 of the catchment area of the basin and one of the oldest lakes in the world, aged over 5 million years old (Figure 1). It is located at the foot of mountain Mitsikeli, its height above sea level is 470m and a major city (Ioannina, pop. 100 000) lies along the western shoreline of the lake (Hela et al., 2005) It is a warm, shallow and eutrophic lake with an average depth of 4.5m and a maximum of 9.5m, with no natural surface outflow outlet (Anagnostidis and Economou-Amilli, 1980). Water from Lake Pamvotis is led to the Kalamas river through the narrow channel of a man-made tunnel and ditch of the ex-lake Lapsista, which has been drained in 50's and converted to agricultural land (Sarika et al., 2019). The volume of the outflow through this connection fluctuates depending on the water level of the lake and it is usually discontinued during summer. Cold wet winters with daily averages <0 ◦C and hot dry summers in excess of 30◦C, describe the climate conditions of the area. The lake joined the NATURA 2000 network in 2003 with Code: N2K GR 2130005. It is a multimixed and limestone lake and the water level drop in summer. The catchment has undergone substantial agricultural, industrial and urban development over the past 40 years which has resulted in cultural eutrophication. From the geological point of view the hydrological basin consists of alluvial deposits, silicious material, clays, tertiary flysch, limestones, and dolomites (Anagnostidis and Economou-Amilli, 1980).

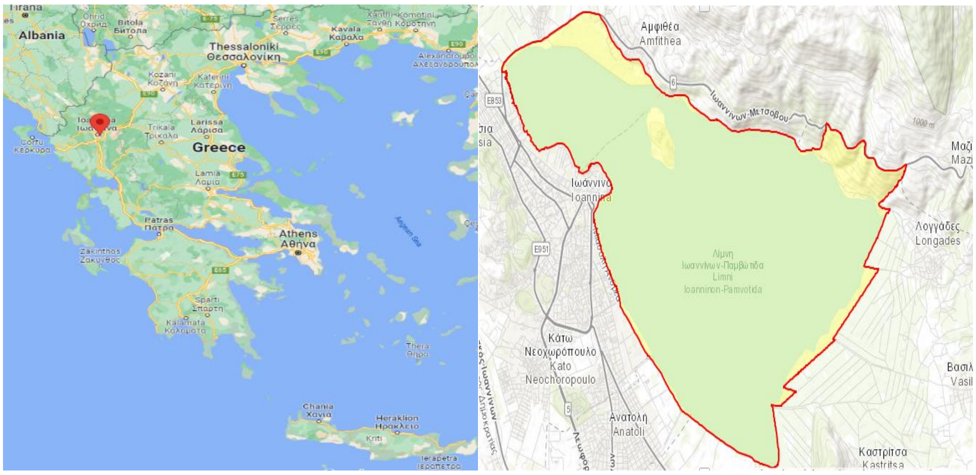

***Figure 1**. Composite figure showing (a) on the left, the location of the Lake Pamvotis in Greece (source: Google Maps) and (b) on the right, the shape of the Lake Pamvotis (source: https://maps.terra.gr). (Accessed in 10/06/2023).*

Materials and Methods

Sample Collection

To control and assess the quality of a lake, it is considered necessary to sampling of lake surface waters over time. By conducting an extensive and reliable sampling of the surface of water from a lake at regular intervals we can extract useful conclusions as to the degree of pollution and the rate of its remediation within the course of time.

The process of sampling the waters of a lake, natural or artificial, is predetermined by the goals that have been set. As a rule, one is built sampling program in which they refer to: the parameters that will determine the number and location of the sampling points, the depths from where samples will be taken, number and type of samples, time and frequency of sampling and the sampling equipment.

Water samples were collected bi-weekly from September 2021 to January 2022, at three sampling-stations in Lake Pamvotis, located in NW Greece (Figure 2). Sites were selected to represent different hydrodynamic environment and different distances from pollution sources. Water samples were collected using a Van Dorn sampler at a depth of 0.5 m and transported to the laboratory in sterilized polyethylene bottles. Samples were kept on ice and analyzed within 24 hours of collection. Water temperature was measured using a sampling column thermometer.

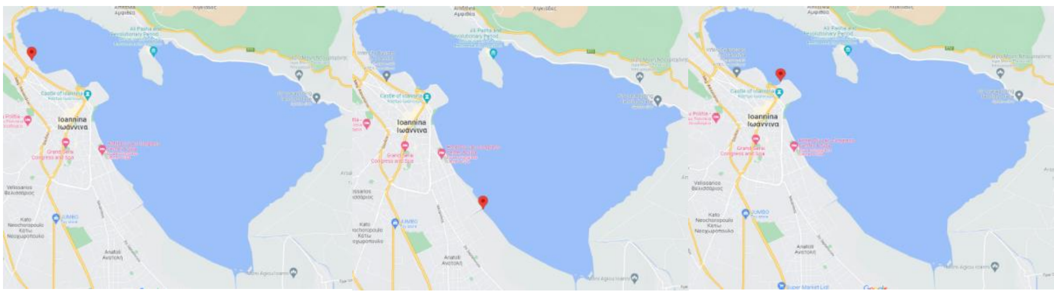

Figure 2. *Collection points (left to right): S1- Ioannina Marine Club Park 39°40'43.5"N 20°50'33.0"E 39.678738, 20.842500, which was used in the first two workshops. S2 – Three bridges, Katsikas 39°38'51.0"N 20°52'23.1"E 39.647485, 20.873069, which was used in the third and fourth lab. S3 – Ioannina Lake Port 39°40'24.8"N 20°51'29.9"E 39.673556, 20.858303, which was used in the fifth and sixth lab (Source: Google maps).*

Participants

Course and Participation

During the winter semester, 2021-2022, 6 workshops lasting 1.5 hours each, were held as part of the course "Introduction to Science Concepts" of the Department of Early Childhood Education of the University of Ioannina. Overall, 160 students participated in the 6 workshops that consisted of 6 groups of 4-5 individuals.

Ethics

To ensure the protection of the participants' privacy and rights, multiple measures were implemented. Anonymous data collection was employed for Mentimeter polls and questionnaires, with no personally identifiable information linked to responses. All research data were stored securely on password – protected electronic devices and data transmissions were encrypted. Informed consent forms were provided to students, detailing research objectives, procedures and voluntary participation, with the option to withdraw at any time. Identification codes, rather than names, were used to anonymize responses upholding ethical research standards and safeguard anonymity.

Workshop Design

The workshop design aimed to engage students actively in hands-on experiments and discussions related to water quality assessment in Lake Pamvotis and comparison with drinkable water. Overall, 26-27 students were assigned to 6 groups of 4-5, and each one of them was allocated to the specific key parameter station that had been designed.

Prior to the conducting of chemical analysis, the students individually began to individually evaluate the organoleptic parameters of water by comparing samples from Lake Pamvotis to simple drinkable water. Subsequently, students assessed a Mentimeter poll scanning QR codes that were placed on its station's workbench that allowed the student direct access to the platform without any registration process. Following this, students worked in their respective groups, each assigned to conduct a different chemical measurement using provided kits and reagents.

Initial Organoleptic Assessment

Students were asked to record the differences they noticed between the drinking water and lake water in terms of the following organoleptic parameters. They were provided with specific instructions on how to assess these parameters, such as sniffing the water to detect any odor, visually comparing the color of the two water samples, tasting them to identify differences in taste, and assessing the level of turbidity by observing any visible particles or cloudiness.

Mentimeter Questionnaire

Mentimeter (https://www.mentimeter.com) is a tool that allows interaction and dialogue with the target audience in real time. It is a polling tool in which questions can be set and the target audience can give their input using a mobile phone or any other internet connected device. It focuses on online collaboration in education, allowing people to answer questions anonymously. The app allows users to share knowledge and feedback in real time with presentations, polls or brainstorming sessions in classes, meetings, gatherings, conferences and other group activities.

Consequently, an online interactive presentation consisting of 20 slides was created including a poll-type multiple-choice questions about the following:

Basic concepts of water quality, such as pH, turbidity, dissolved oxygen, and nutrient levels.

Knowledge of different freshwater ecosystems and their characteristics.

Understanding of the effects of human activities on water quality, such as pollution and climate change.

Familiarity with different tools and techniques for measuring and interpreting chemical parameters in a freshwater ecosystem, such as water sampling, chemical analysis, and data interpretation.

Descriptive statistics, including frequencies, percentages, means and standard deviations, were used to analyze the data.

Chemical Analysis

Chemical parameters of the water samples were analyzed using standard methods. Six stations were set up for measuring the following parameters: pH, ammonium, phosphates, total hardness, nitrites, and nitrates. Each parameter was measured using its corresponding reagent kit (pH meter, Nessler reagent, ammonium reagent, phosphate reagent, Griess reagent, and cadmium reduction method, respectively). All measurements were performed in triplicate, and the average values were used for analysis.

Results

Organoleptic parameters

At the outset of the workshops, both containers of drinking water and samples from Lake Pamvotis were placed on the students' workbenches. Most students participating in the study collectively recorded their initial observations, revealing noteworthy distinctions between the two sources of water.

Odor**:** In their assessments, all students unanimously described the tap water as odorless. However, when it came to the water from Lake Pamvotis, their observations diverged, with various students noticing the presence of different smells, such as those reminiscent of fish and seaweed.

Color**:** Students consistently characterized the tap water as colorless and transparent. In stark contrast, their collective perception of Lake Pamvotis water was a pale yellow and greenish color.

Taste**:** Interestingly, students found it challenging to discern notable differences in taste during the initial assessment. Most students described the tap water as tasteless, while they suspected that the lake water had an unfavorable taste.

Turbidity**:** In terms of turbidity, students observed clear differences. Tap water was praised for its absolute clarity. On the other hand, students noticed considerable turbidity in Lake Pamvotis water. Some students used descriptive phrases like "I don't see the other side of the bottle like in drinking water", and "I see something like mud or dirt in the water". Additionally, they observed suspended solids in the lake water, describing the presence of "dirt, garbage, animals, etc.".

4.2. Mentimeter results

The figures of the results of the Mentimeter survey are presented in the Annex. The key findings from the Mentimeter survey are arranged per question and can be summarized as follows:

What is the water quality, and why it so important?

Most participants (43,75%) correctly identified water quality as the measurement of water's chemical and physical characteristics. However, an equal percentage associated it with the taste and smell of water, while a smaller percentage (12,5%) linked it to water quantity and availability.

What are the primary factors that influence the water quality in a freshwater ecosystem?

A significant portion (43,75%) recognized that both human activities and natural processes impact water quality. Additionally, an equal percentage (43,75%) correctly attributed it to the availability of nutrients and oxygen, while 12,5% mentioned temperature and precipitation.

What is pH, and how does it impact water quality?

Surprisingly, only 5 % correctly defined pH as a measure of water's acidity or basicity. Most respondents (43,75%) connected it with either turbidity and clarity or salinity and dissolved solids, respectively. Finally, 12,5% defined it as a measure of water's temperature and depth.

What is turbidity, and how does it affect water quality?

A significant percentage (43,75%) understood turbidity as the clarity or cloudiness of water, which directly impacts water quality. Another 43,75% associated it with the number of pollutants in the water while others chose 'the presence of microscopic organisms' (12,5%) and 'the amount of dissolved oxygen in water' (5%).

What is dissolved oxygen, and why it is important for aquatic life?

Most participants (43,75%) selected 'the amount of oxygen that is produced through respiration' and 'the amount of oxygen that is used up during photosynthesis'. While 12,5 % associated dissolved oxygen with the amount of oxygen released from plants in water, and only 5 % with the amount of oxygen in water that is available for aquatic organisms to breathe.

What are some sources of pollution that can affect water quality in a freshwater ecosystem?

Most participants (43,75%) identified either climate change and global warming or the presence of fish and other aquatic organisms (43,75%) while only 12,5 % attributed pollution with agricultural runoff and industrial discharge and natural processes and weather events (5%).

What is eutrophication, and how does it affect water quality?

For most eutrophication is either the process by which dissolved oxygen is depleted in water (43,75%) or the process by which pollutants accumulate in water (43,75%), while 12,5% selected 'the process by which aquatica plants use nutrients to grow and reproduce and 5% defined it as the process by which algae blooms occur in water.

What are some common methods for measuring and interpreting chemical parameters in a freshwater ecosystem?

In this question the most popular answers were that of 'Satellite imagery and remote sensing' (43,75%) and 'Computer simulations and mathematical models' (43,75%) while 'water sampling and laboratory analysis' was voted by 12,5% and only 5% selected 'Visual inspection and field observations'.

How can data on chemical parameters in a freshwater ecosystem be used to assess water quality?

Only 5 % of the participants voted 'to track changes in water quality over time and monitor ecosystem health, followed by 12,5% that preferred 'to identify sources of pollution and develop remediation strategies. Finally 43,75% selected 'to evaluate the effectiveness of environmental policies and regulations' and 43,75% 'all the above'.

What are some potential impacts of climate change on water quality in a freshwater ecosystem?

In that question the most popular answers were 'all the above' and 'changes in nutrient and pollutant levels' that received 43,75 % respectively. Only 5 % preferred 'increases in storm intensity and frequency' and 12,5% 'changes in water temperature and availability'.

Did you know what the presence of nitrites (above limits) causes in the water lake?

In the question about whether the students know what causes the presence of nitrites above the limits in the lake water, 86.5% answered no, while only 13.5% said yes.

The main source of phosphates in the lake water is:

When asked what the main source of phosphate in the lake water is, the 160 participants answered as follows. 43.75% (i.e. 70 students) consider that the main source is the industrial waste discharged into the lake, the other 43.75% consider it to be from soil, while only 12.5% (20 students) answered that it is due in synthetic detergents which is also the right answer.

The turbidity in the lake water:

A total of 66 (41.25%) of the 160 students answered that the turbidity in the water of a lake does not allow the passage of light. The remaining 94 gave incorrect answers, with 47 thinking that haze allows light to pass through and the other 47 thinking that it reflects it.

We want the pH of the lake to be:

The question about the Ph of the lake water was answered correctly by 28 students with a percentage of 17.5%. Most (79) with a percentage of 49.375% consider that the Ph of the lake water should always be neutral, while 28 with a percentage of 17.5% consider that it should be acidic.

Nitrates in the lake water

In the question about nitrates in the lake water, the largest percentage of students 51.25% answered incorrectly with 82 considering that nitrates are food for phytoplankton and zooplankton. The next highest percentage of 33.125% with 53 out of 160 answered correctly stating that they come from animal excrement and fertilizers while the lowest of all 15.625% with 25 students answered that they break down into carcinogenic substances.

What do you think is the cause of eutrophication?

One of the most critical issues of a lake ecosystem, the phenomenon of eutrophication is considered by a significant percentage of students 57.5% to be due to excessive vegetation and by a smaller percentage of 23.75% to overfishing. The smallest percentage of 18.75% with only 30 students answered correctly that the presence of nutrient salts is responsible for creating eutrophication.

The smell, color, turbidity, and taste of lake water belong to:

When asked about the classification of smell, odor, turbidity and taste of lake water, 24,38% correctly categorized them as organoleptic parameters, while 27,5% erroneously attributed them to microbiological parameters and 48,13% categorized them as chemical.

Chemical Analysis

pH

The chemical analysis aimed to assess and compare key water quality parameters in Lake Pamvotis and drinking water. To accomplish this, three methods of pH measurements were employed: pH indicators, density papers, and a digital pH meter. In addition to Lake Pamvotis water, measurements were also conducted on drinking water to provide a comprehensive assessment of the water quality (Table 1).

Workshop/Team	Sample location	pH method		
		pH Indicator	Density Paper	Digital pH Meter
1	S1	7	6	8,1
2	S1	6	6	8
3	S2	7.5	6	6.2
4	S2	8	7	6.2
5	S3	5	6	8.4
6	S3	6	6.5	8.8

Table 1. *pH measurements of Samples per measurement method*

The pH measurements across the six workshops and different sampling locations exhibit noticeable variations. In the workshops using samples from S1, we observe that the pH values tend to be around 7 for both the Ph indicator and density paper methods. However, the digital pH meter records slightly higher values, notably 8.1 and 8.0 for Workshops 1 and 2, respectively. When comparing the pH of the lake samples (S1, S2, S3) to that of tap water, it is evident that there are consistent differences. Lake water displays a pH around 7, whereas tap water consistently records higher pH values, ranging from 8.0 to 8.8.

The three different pH measurement methods yield varying results, and this discrepancy may be attributed to the precision of the measurement instruments. These pH measurements need to be considered in the context of our research question, which explores the alignment between scientific measurements and sensory perceptions in assessing water quality. Preliminary organoleptic assessments noted that students perceived lake water to have an unpleasant taste and odor. The pH measurements indicate that lake water tends to be more neutral ($pH \approx 7$) compared to tap water ($pH > 8$), suggesting that taste and odor perceptions may not be strongly correlated with pH levels in this context.

These pH measurements provide valuable insights into the chemical characteristics of the water samples. While pH is an important parameter for water quality assessment, other factors may contribute to the sensory perceptions noted by the students. Further investigation into additional water quality parameters may help elucidate the factors contributing to these sensory perceptions.

NH_4^+

Accordingly, this section aims to assess NH_4^+ (Ammonium) variations across locations and water types. Table 2 summarizes NH_4^+ measurements in milligrams per liter (mg/L) for drinking water and lake water at different sampling locations. Notable variations were observed among teams for the same sample. In the first experiment at S1 (Marine Park), one group measured 0.2 mg/L in lake water, while the other found 1 mg/L. At S2 (Three Bridges), one group detected 0.2 mg/L in lake water, while the other found 0 mg/L.

The 3d experiment from sample from S3 (Port of the Lake) revealed contradictory results within teams, with one group identifying drinking water as more polluted, while the other disagreed on the workshop 6. Both groups agreed that the lake at this location had NH_4^+ concentrations ranging from 0.2 to 0.5 mg/L.

Workshop	Sample location	Drinking Water (mg/L)	Lake Water (mg/L)
1	S1	0.2	0.2
2	S1	0.2	1
3	S2	0.2	0.2
4	S2	0.2	0
5	S3	0.2	0.5
6	S3	1	0.2

Table 2. *NH4+ Measurements*

The variations suggest subjectivity in assessing water quality based on NH_4^+ levels. This highlights the importance of considering scientific measurements and sensory perceptions. Perceptions of lake water pollution did not always align with measurements. In some cases, lake water was perceived as more polluted, while in others, it was the opposite.

Equipment calibration, sampling techniques and subjectivity may have influenced variations (Photo 1). Workshops focused on sensory assessments, potentially affecting participant's perceptions.

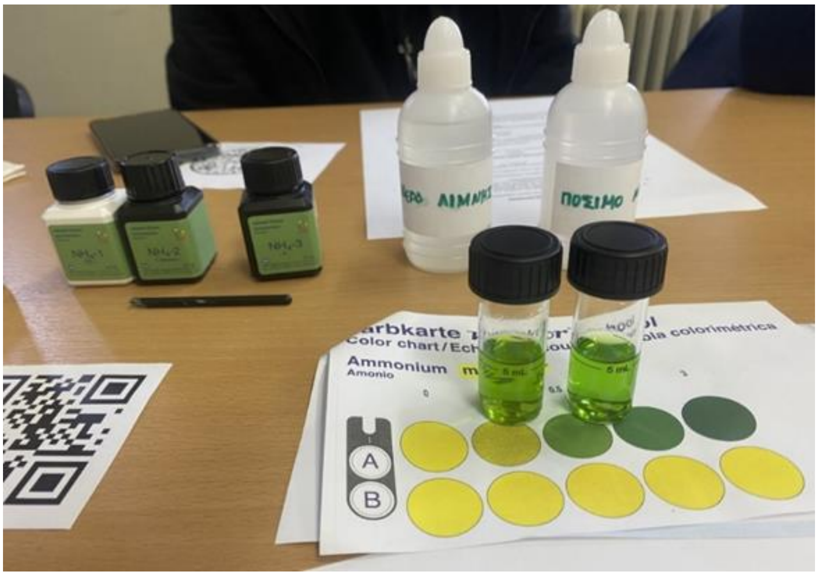

Photo 1*. Measurement results NH4+ Group 1*

NH_4^+ measurements revealed variations in water quality perceptions across workshops and locations. These findings underscore the need for comprehensive assessments considering both scientific measurements and sensory perceptions.

Total Hardness

Table 3 summarizes total hardness measurements for both drinking water and lake water at different sampling locations.

Workshop	Sample location	Drinking Water (mg/L)	Lake Water (mg/L)
1	S1	302.6	213.6
2	S1	302.6	142.4
3	S2	302.6	106.8
4	S2	302.6	64.68
5	S3	302.6	106.8
6	S3	302.6	267

Table 3. *Total Hardness measurements*

The results show consistent trends across workshops. Drinking water consistently exhibited higher total hardness than lake water. Despite variations in lake measurements, drinking water total hardness remained constant across all workshops suggesting a stable characteristic. The observations highlight a common misconception among participants regarding the hardness of drinking water compared to lake water. Integrating scientific measurements alongside sensory perceptions is crucial for accurate water quality assessments.

Total hardness measurements revealed variations in water hardness among workshops and locations in Lake Pamvotis. These findings emphasize the need for a comprehensive approach to water quality assessment that considers both scientific measurements and organoleptic parameters.

Phosphates

Phosphate measurements are summarized accordingly for both drinkable water and lake water in table 4.

Workshop	Sample location	Drinking Water (mg/L)	Lake Water (mg/L)
1	S1	0	0
2	S1	0	0,5
3	S2	0	0.25
4	S2	0	0.5
5	S3	0	0.5
6	S3	0	0.5

Table 4. *Phosphate measurements*

The results indicate notable trends among workshops. In sample of S1 both teams of workshops 1 and 2 respectively recorded phosphate values of zero for both drinking water and lake water, indicating no detectable phosphate ions. In the sample of S2, teams of workshops 3 and 4 recorded 0.5 mg/L and 0.25 mg/L respectively with the results of teams of workshops 5 and 6 to be similar with zero phosphate in drinkable water and a phosphate concentration of 0.5 mg/L.

The consistency in phosphate measurements suggests an agreement among participants in assessing water quality based on phosphate levels. However, the lake water's phosphate levels failing within the normal range despite perceptions of lake pollution may indicate a disparity between sensory observations and scientific measurements.

The findings underscore the importance of integrating sensory perceptions and scientific measurements for comprehensive water quality assessments.

Nitrate (NO_3^-)

Nitrate (NO_3^-) measurements are essential for evaluating water quality and assessing potential sources of pollution. Table 5 summarizes *Nitrate (NO_3^-)* measurements in milligram per liter (mg/L).

Workshop	Sample location	Drinking Water (mg/L)	Lake Water (mg/L)
1	S1	10	0
2	S1	5	0
3	S2	5	1
4	S2	5	1
5	S3	5	0-1
6	S3	10	0-1

Table 5. *Nitrate (NO3-) Measurements*

The results reveal discrepancies between student's expectations and the actual nitrate levels in the water sources. Drinking water consistently displayed higher nitrate concentrations than lake water. This emphasizes the importance of routine water quality monitoring and adherence to safety standards. Variations in color perception, calibration of equipment, and sampling methods could have influenced the results (Photo 2).

Photo 2. Measurement results NO3- Group 3 on the left, and Group 5 on the right

Nitrate measurements indicated surprising differences between drinking water and lake water, contradicting students' perceptions.

Nitrite (NO_2^-)

The results from the last measurement confirm the previous not only highlighting the variability in perception but also emphasize the need for comprehensive water quality assessments considering both quantitative measurements and sensory observations (Table 6).

Workshop	Sample location	Drinking Water (mg/L)	Lake Water (mg/L)
1	S1	10	0
2	S1	5	0
3	S2	5	1
4	S2	5	1
5	S3	5	0-1
6	S3	10	0-1

Table 6. *Nitrite (NO2-) Measurements*

Discussion

The study's findings regarding perception versus scientific measurement align closely with our first subquestion: "What are the scientific measurements (pH, Ammonium, Phosphates, Total Hardness, Nitrites and Nitrates) that define water quality in Lake Pamvotis?" The cognitive dissonance observed highlights the disparities between students' perceptions and the scientifically established parameters used to define water quality. This disconnect underscores the critical importance of addressing misconceptions and enhancing public understanding of the scientific aspects of water quality (De Franca Doria, 2010)

The significance of environmental education, as indicated by our study's findings, directly addresses our second subquestion: "How do sensory perceptions (odor, color, taste, turbidity) of water quality in Lake Pamvotis compare with scientific measurements and student assessments?" The data emphasize that effective educational programs can play a pivotal role in aligning sensory perceptions with scientific concepts, thereby fostering a more holistic understanding of water quality.

Our investigation into areas where misconceptions persist, particularly in understanding key parameters ties into our third subquestion: "To what extend do student assessments align with scientific measurements when assessing water quality in Lake Pamvotis?" The knowledge gaps identified underscore the need for targeted educational interventions aimed at rectifying these misconceptions and promoting accurate interpretations of scientific measurements.

Finally, our study's broader implications align with the overarching research question: "How do scientific measurements and sensory perceptions align with assessing water quality in Lake Pamvotis and drinkable water?" The data emphasize that misconceptions and knowledge gaps pose significant challenges to aligning sensory perceptions with scientifically established water quality parameters. By addressing these challenges through effective environmental education, we can empower individuals to participate actively in environmental conservation efforts and bridge the gap between perception and science.

Our data specifically also sheds light on specific areas where misconception persist, notably in understanding parameters such as Ph, turbidity, nitrites, and phosphates. These knowledge gaps emphasize the need for targeted educational interventions to enhance public awareness and promote accurate interpretations of scientific measurements. The findings have direct implications for environmental conservation and the sustainable management of freshwater ecosystems. By rectifying misconceptions and fostering a deeper understanding of water quality, educational initiatives can equip individuals with the knowledge and motivation to engage in responsible environmental stewardship.

Conclusion

This study explored the alignment between scientific measurements and sensory perceptions in assessing water quality in Lake Pamvotis and drinking water. Key findings include:

Scientific measurements revealed the dynamic nature of water quality, influenced by environmental factors and human activities.

Sensory perceptions, while subjective, serve as a vital link between individuals and their environment, impacting environmental attitudes.

Alignment and discrepancies between sensory perceptions and scientific measurements were observed, emphasizing the need to bridge this gap.

Environmental education plays a pivotal role in promoting informed decision-making and sustainable practices.

In summary, this research highlights the importance of comprehensive water quality assessment that considers both scientific data and sensory experiences. Bridging the divide between objective measurements and subjective perceptions is essential for effective environmental stewardship and sustainable resource management.

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Annex

In the following figures, the results of the students' answers to the Mentimeter survey are presented.

1. What is water quality, and why is it important?

a. The measurement of water's quantity and availability.
b. The measurement of water's temperature and depth.
c. The measurement of water's chemical and physical characteristics.
d. The measurement of water's taste and smell.

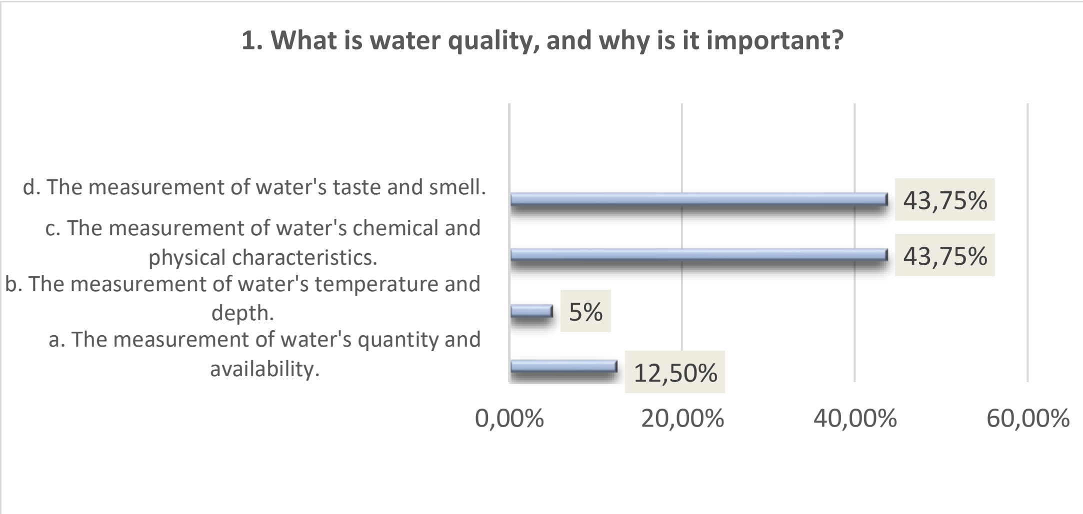

Figure 1. *What is water quality and why is it important?*

2. What are the primary factors that influence water quality in a freshwater ecosystem?

a. Temperature and precipitation.
b. Climate change and land use.
c. Human activities and natural processes.
d. The availability of nutrients and oxygen.

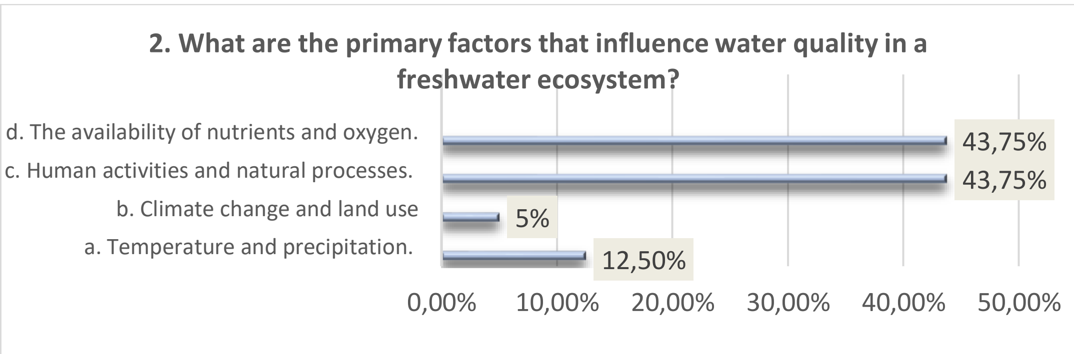

Figure 2. *What are the primary factors that influence water quality in a freshwater ecosystem?*

3. What is pH, and how does it impact water quality?
a. A measure of water's temperature and depth.
b. A measure of water's acidity or basicity.
c. A measure of water's salinity and dissolved solids.
d. A measure of water's turbidity and clarity.

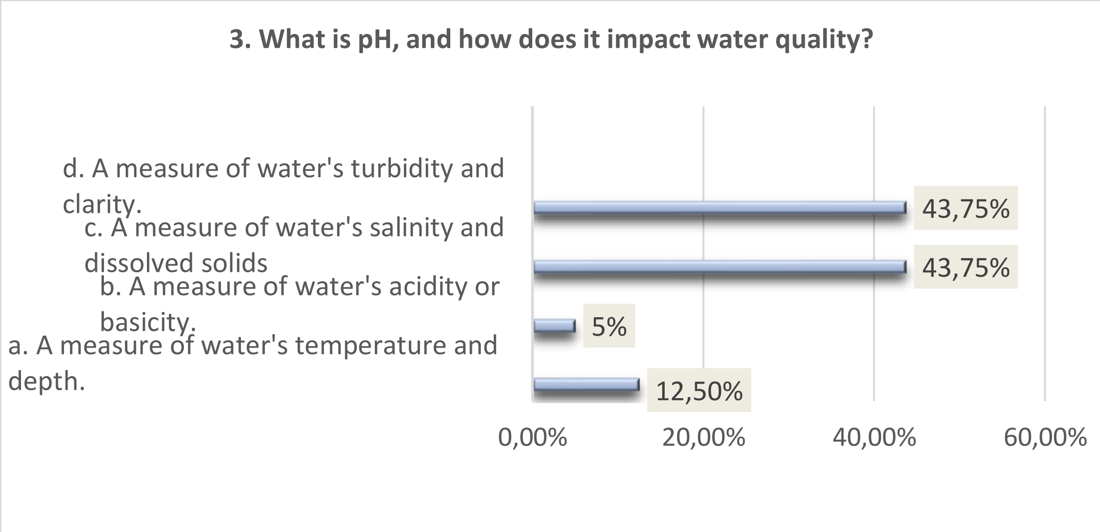

Figure 3. *What is pH, and how does it impact water quality?*

4. What is turbidity, and how does it affect water quality?
a. The presence of microscopic organisms in water.
b. The amount of dissolved oxygen in water.
c. The clarity or cloudiness of water.
d. The amount of pollutants in water.

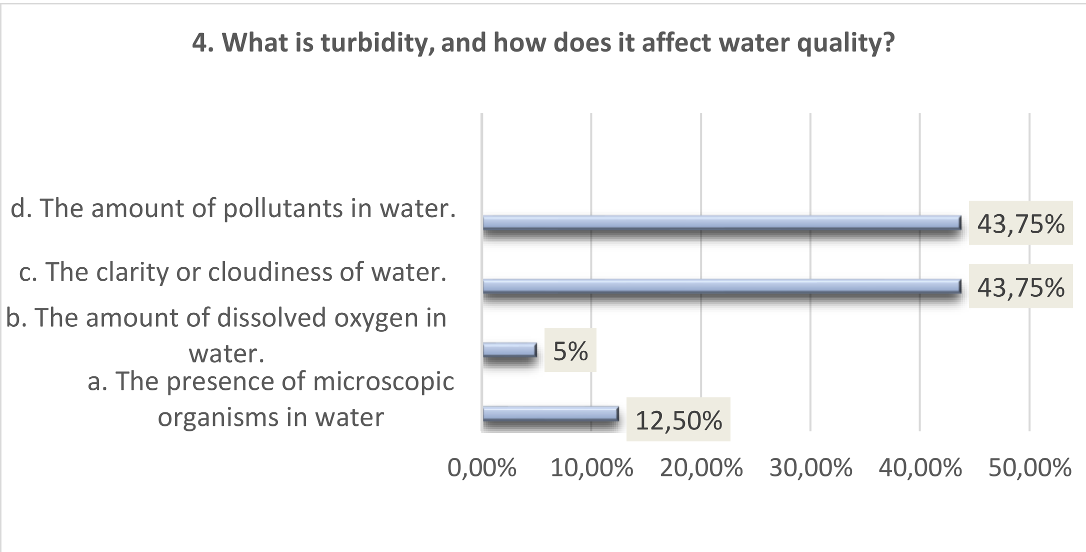

Figure 4. *What is turbidity, and how does it affect water quality?*

5. What is dissolved oxygen, and why is it important for aquatic life?
a. The amount of oxygen released from plants in water.
b. The amount of oxygen in water that is available for aquatic organisms to breathe.
c. The amount of oxygen that is used up during photosynthesis.
d. The amount of oxygen that is produced during respiration.

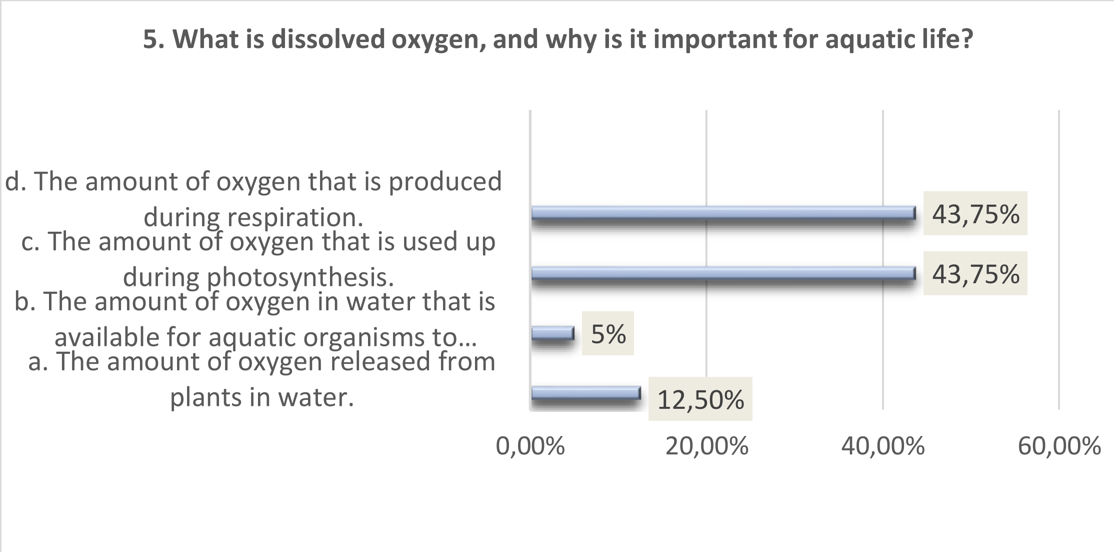

Figure 5. *What is dissolved oxygen, and why is it important for aquatic life?*

6. What are some sources of pollution that can affect water quality in a freshwater ecosystem?
a. Agricultural runoff and industrial discharge.
b. Natural processes and weather events.
c. The presence of fish and other aquatic organisms.
d. Climate change and global warming.

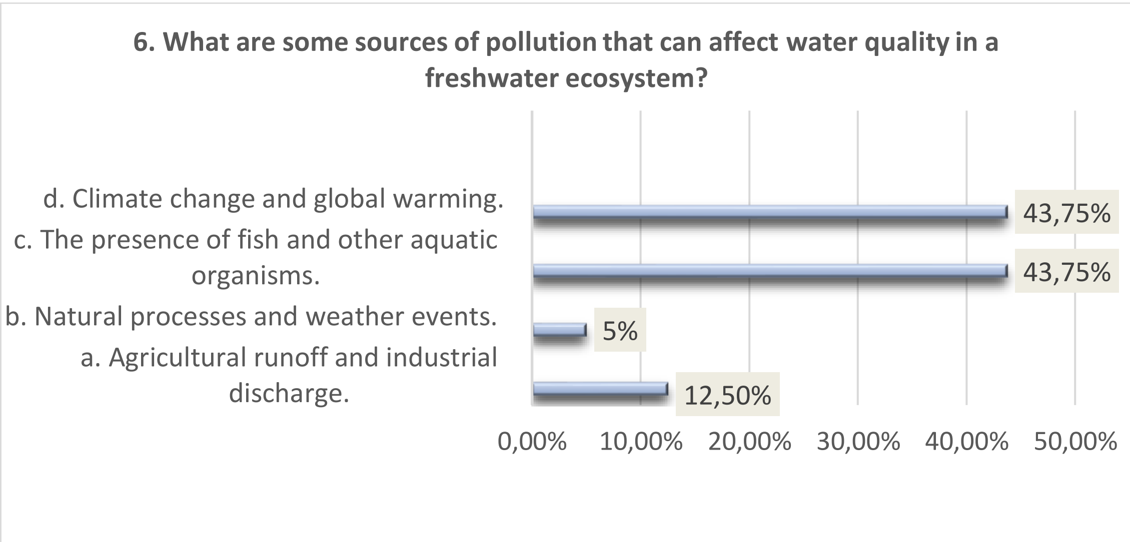

Figure 6. *What are some sources of pollution that can affect water quality in a freshwater ecosystem?*

7. What is eutrophication, and how does it affect water quality?
a. The process by which aquatic plants use nutrients to grow and reproduce.
b. The process by which algae blooms occur in water.
c. The process by which pollutants accumulate in water.
d. The process by which dissolved oxygen is depleted in water.

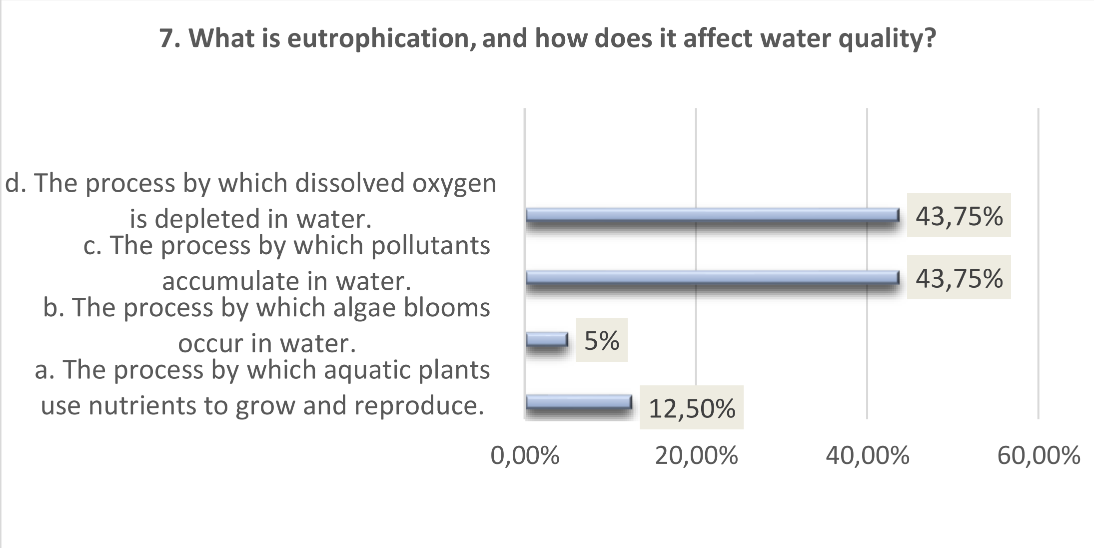

Figure 7. *What is eutrophication, and how does it affect water quality?*

8. What are some common methods for measuring and interpreting chemical parameters in a freshwater ecosystem?
a. Water sampling and laboratory analysis.
b. Visual inspection and field observations.
c. Computer simulations and mathematical models.
d. Satellite imagery and remote sensing.

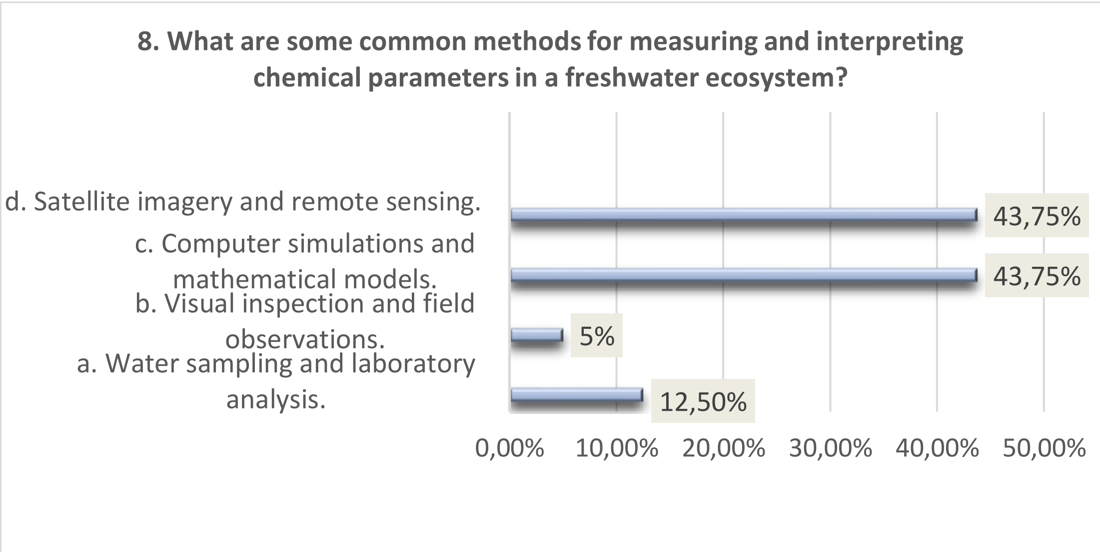

Figure 8. *What are some common methods for measuring and interpreting chemical parameters in a freshwater ecosystem?*

9. How can data on chemical parameters in a freshwater ecosystem be used to assess water quality?

a. To identify sources of pollution and develop remediation strategies.
b. To track changes in water quality over time and monitor ecosystem health.
c. To evaluate the effectiveness of environmental policies and regulations.
d. All of the above.

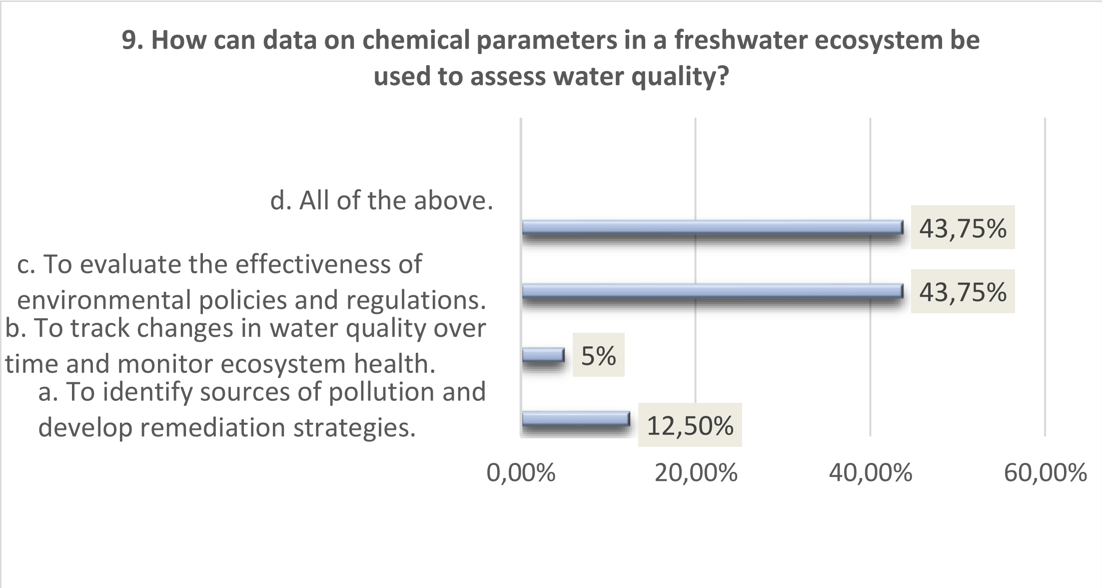

Figure 9. *How can data on chemical parameters in a freshwater ecosystem be used to assess water quality?*

10. What are some potential impacts of climate change on water quality in a freshwater ecosystem?

a. Changes in water temperature and availability.
b. Increases in storm intensity and frequency.
c. Changes in nutrient and pollutant levels.
d. All of the above.

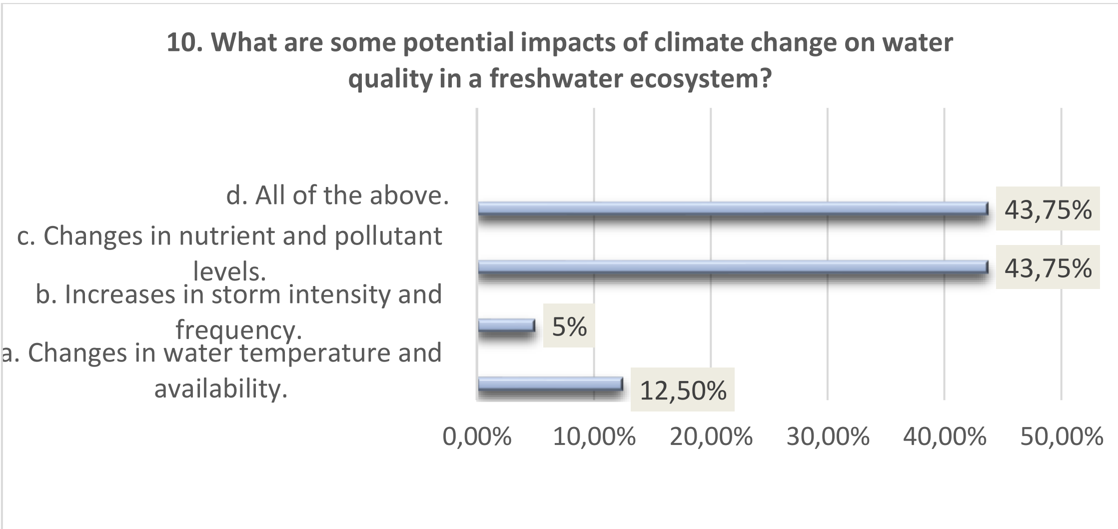

Figure 10. *What are some potential impacts of climate change on water quality in a freshwater ecosystem?*

11. Do you know what the presence of nitrires (above limits) causes in the water lake?
NO
YES

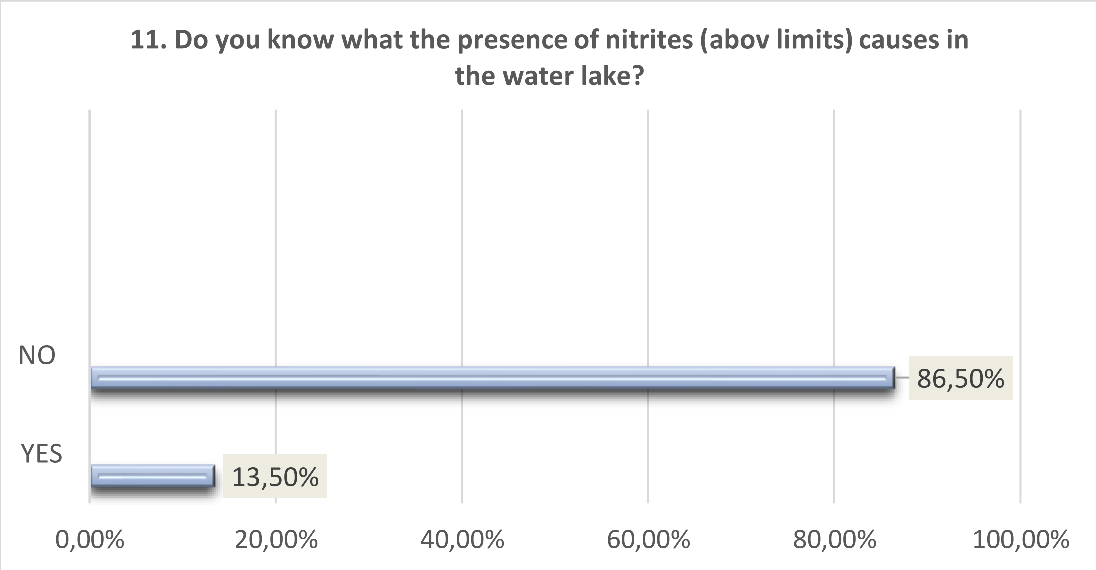

Figure 11. *Do you know what the presence of nitrires (above limits) causes in the water lake?*

12. The main source of phosphate in the lake water is:
a. Synthetic detergents
b. Industrial waste
c. Soil

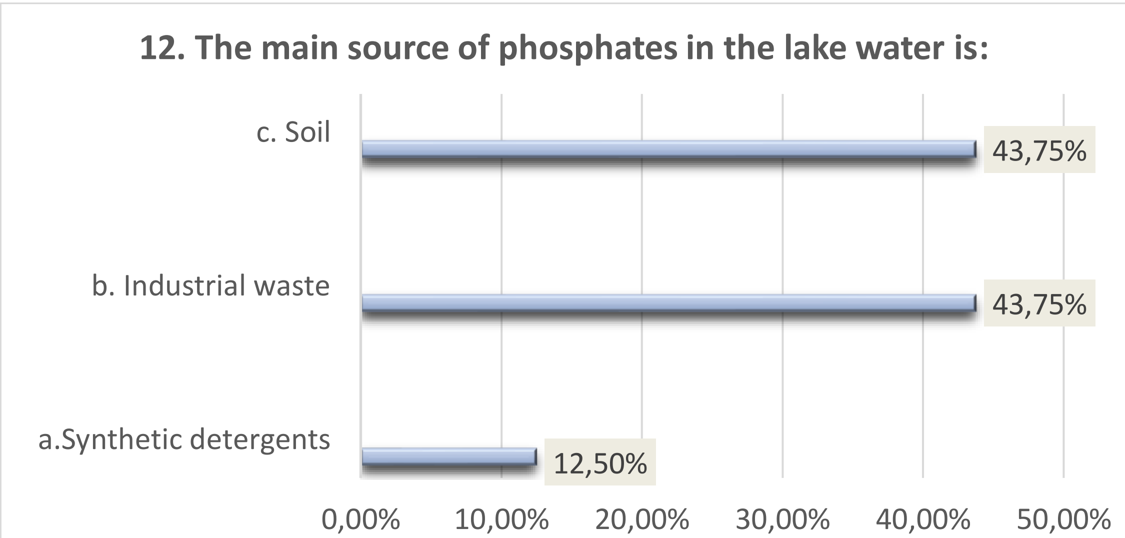

Figure 12. *The main source of phosphate in the lake water*

13. The turbidity in the lake water:
a. It does not allow light to pass through.
b. Allows light to pass through.
c. It reflects light.

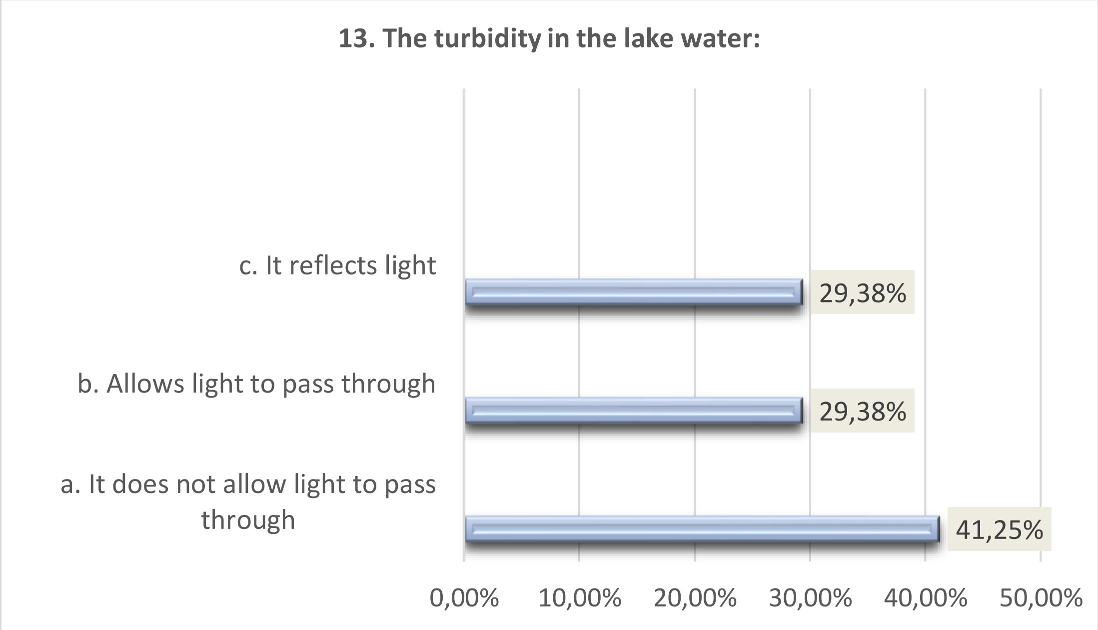

Figure 13. *The turbidity in the lake water*

14. We want the pH of the lake water to be:
a. Always neutral
b. Slightly acidic
c. Slightly alkaline

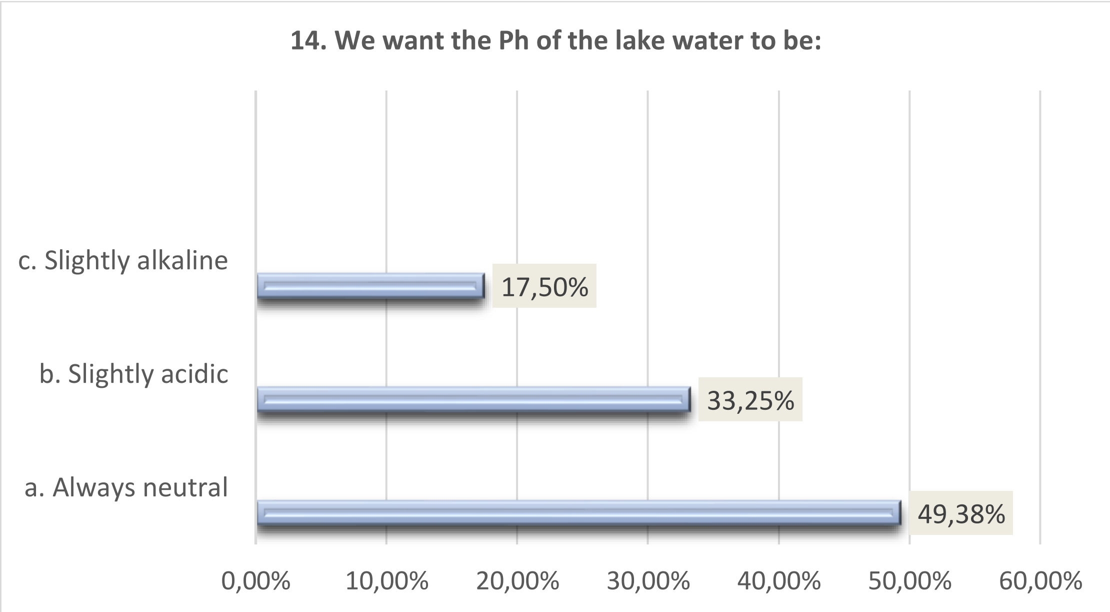

Figure 14. *We want the pH of the lake water to be*

15. Nitrates in lake water:
a. They break down into carcinogenic substances.
b. They are food for phytoplankton and zooplankton.
c. They come from animal excrement and fertilizers.

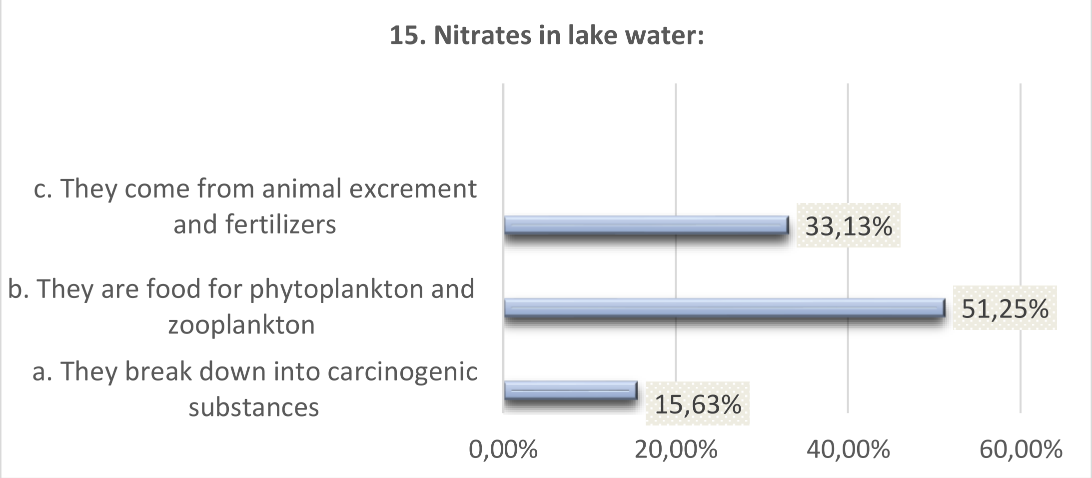

Figure 15. *Nitrates in lake water*

16. What do you think is the cause of eutrophication?
a. Excessive presence of nutrients
b. Excessive vegetation
c. Overfishing

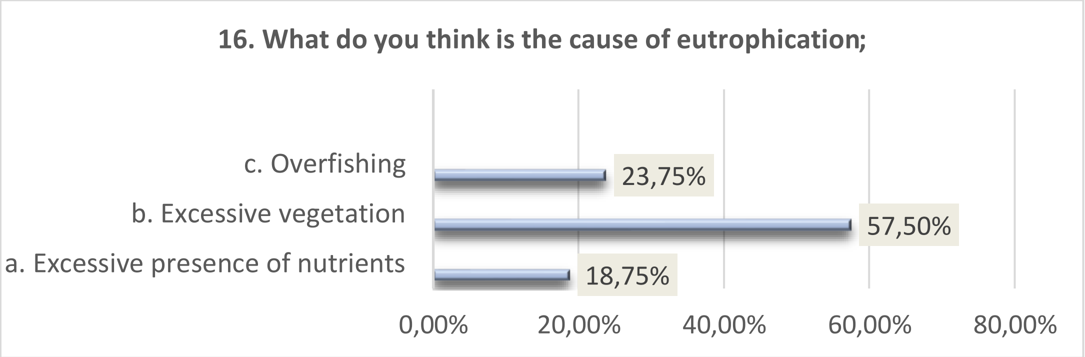

Figure 16. *What do you think is the cause of eutrophication?*

17. The smell, color, turbidity and taste of lake water belong to:
a. Microbiological parameters
b. Organoleptic parameters
c. Chemical parameters.

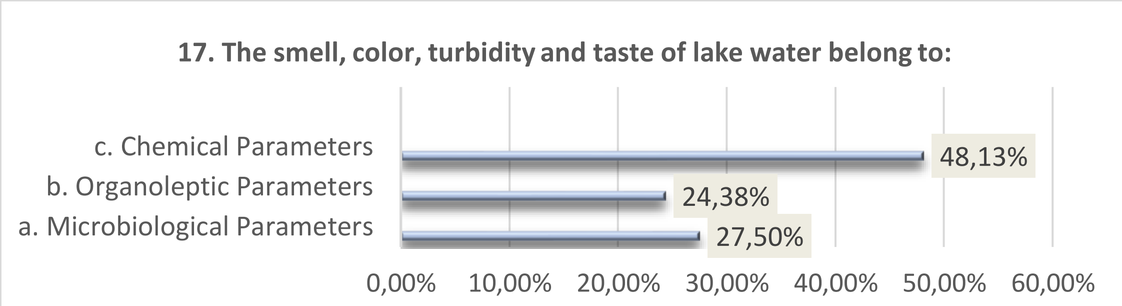

Figure 17. *The smell, color, turbidity and taste of lake water belong to:*

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Prouska, K., Potsikas, M., Efthimiou, G., Plakitsi, K. (2023). **Assessing Water Quality and Future Kindergarten Teachers' Perceptions in a Freshwater Ecosystem: A Multifaceted Study**. *Science Education Research and Praxis*, (87-88): 33-55. ISSN 1792-3166**,** Retrieved from https://serp.ecedu.uoi.gr/