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Assessing in-service chemistry teachers' environmental literacy on hydrosphere pollution

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Abstract

Effective environmental education depends on teachers who possess both scientific understanding and the ability to translate it into meaningful classroom practice. In this study, the environmental literacy (EL) of in-service chemistry teachers regarding hydrosphere pollution was investigated. An online instrument assessed environmental knowledge, competencies, dispositions, and environmentally responsible behaviour across five critical topics: agricultural runoff, ocean acidification, microplastics, e-waste, and persistent organic pollutants. Data from 66 in-service teachers revealed a moderately low overall EL, with limited knowledge, varied competencies, and frequent misconceptions, especially on newer issues. Teachers demonstrated strong pro-environmental dispositions but exhibited inconsistent behaviour. Neither participation in in-service education nor the educational level at which teachers teach showed significant differences in their EL. The results highlight the discrepancy between positive dispositions and actionable knowledge and competencies. These findings indicate the need to reconsider and strengthen the design of in-service education programmes and the curricular integration of hydrosphere pollution issues.

Keywords: environmental education, environmental literacy, chemistry teachers, hydrosphere pollution, professional development

INTRODUCTION

Human activities have profoundly altered the natural world, contributing to pollution, climate change, resource depletion, and biodiversity loss (Intergovernmental Panel on Climate Change, 2021; Steffen et al., 2015). Among these environmental challenges, water pollution stands out as one of the most urgent issues, primarily caused by human activity. Since water is essential for life, addressing this problem is critical for ensuring the health of ecosystems and communities (United Nations, n.d.). To tackle such environmental concerns effectively, it is vital to educate environmentally conscious individuals with well-developed environmental literacy (Kaya & Elster, 2019; Yeh et al., 2022).

As the consequences of human actions become more apparent, the role of environmental education (EE) has become increasingly important as a key tool for raising awareness, improving environmental attitudes, supporting sustainable behaviours and empowering young individuals to act for the environment (Dogan et al., 2025; Tilbury, 2011). EE in combination with science education develops environmental literacy (Wals et al., 2014).

Defining Environmental Literacy

Different authors propose different definitions of environmental literacy (EL) however all definitions include certain key elements such as knowledge of environmental issues, attitudes towards the environment, perceptions of environmental use, and care for the environment (Husamah et al., 2022; Liu et al., 2015; Maurer & Bogner, 2020; Szczytko et al., 2018). These elements are similar to those elaborated 50 years ago at the 1977 UNESCO-UNEP intergovernmental conference, where it was agreed that the following

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Contribution to the literature

- The study provides the first comprehensive assessment of in-service chemistry teachers' environmental literacy focused on hydrosphere pollution issues.
- A multidimensional framework combining four-tier diagnostic knowledge tasks with competency, dispositional and behavioural measures for a holistic evaluation was applied.
- The findings reveal a gap between chemistry teachers' strong environmental dispositions and limited knowledge and competencies

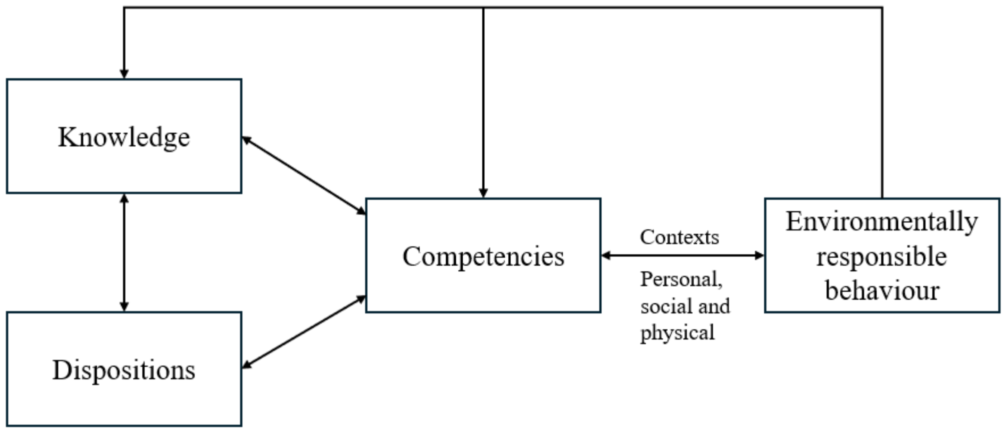

Figure 1. Main dimensions of the EL domain (Hollweg et al., 2011)

objectives should be achieved in order to reach the EL of the general public:

(1) Awareness and sensitivity to the total environment and related problems;

(2) Knowledge to gain diverse experience of and a basic understanding of the environment and related problems;

(3) Attitudes of concern for the environment and motivation to take an active part in improving and protecting it;

(4) Skills to solve environmental problems; and

(5) Participation to take an active part in solving environmental problems at all levels (UNESCO, 1978).

In 1992 Disinger and Roth offered the first widely accepted definition of EL, describing it as "the capacity to perceive and interpret the relative health of environmental systems and take appropriate action to maintain, restore or improve the health of those systems" (Disinger & Roth, 1992, p. 2).

For this study chemistry teachers' EL was assessed based on the framework proposed by Hollweg et al. (2011) who define EL as: "Knowledge of environmental concepts and issues; the attitudinal dispositions, motivation, cognitive abilities, and skills, and the confidence and appropriate behaviours to apply such knowledge to make effective decisions in a range of environmental contexts. Individuals demonstrating degrees of EL are willing to act on goals that improve the well-being of other individuals, societies, and the global environment, and can participate in civic life" (Hollweg et al., 2011, pp. 5-15, 5-16).

The framework is based on the EL domain (**Figure 1**), which consists of four interrelated components:

(1) Environmental knowledge,

(2) Dispositions toward the environment

(3) Environmental competencies, and

(4) Environmentally responsible behaviour.

Teachers' Environmental Literacy

Although there is much research on EL in general, very little has been conducted on in-service teachers. The study by Liu et al. (2015) assessed the EL of in-service elementary and secondary school teachers across Taiwan to establish a national baseline and support the development of environmental education policies and training. EL was assessed based on teachers' knowledge, attitudes/values and actions. The results showed that teachers in Taiwan have a solid foundation of environmental values and knowledge but lack experience and confidence in implementing environmental actions. In the study by Gkargkavouzi et al. (2018), the authors examined the environmental knowledge, attitudes, and pro-environmental behaviour of Greek teachers. It was found that teachers are generally very interested in nature and exhibit pro-environmental behaviours. However, they have knowledge gaps, especially regarding complex concepts such as sustainability and biodiversity loss. The authors suggest that to improve their EL, both content knowledge and emotional connection to nature need to be improved. Kidman and Casinader (2018) point to a critical gap in teachers' EL that negatively impacts student outcomes. To develop EL in a meaningful way, the authors suggest that teachers need both environmental and inquiry skills, but also explicit support for sustainability, rather than relying on optional or curriculum-included content. They also emphasise that teacher education needs to evolve to prepare teachers for the demands of EE in a complex, interconnected world. The study from Garcesa and Limjuco (2014) assessed the relationship between EL and the integration of environmental issues in science teaching among 400 high school teachers in Philippines. While teachers demonstrated high environmental knowledge, their pro-environmental behaviour and practices in integrating environmental issues in the classroom were less developed. Most teachers valued EE and intended to incorporate it into their teaching, but practical application, especially using experiential methods, was limited. The study found a strong positive correlation between EL and integration practices, suggesting that targeted in-service teacher education is needed to bridge the gap between environmental understanding and implementation in the classroom. A newer study from the Philippines performed by Garcia and Cobar-Garcia (2022) examined the EL of elementary and high school teachers, and assessed their knowledge, scientific competencies, attitudes, and pro-environmental behaviours. The results showed that while the teachers generally had positive environmental attitudes, their environmental knowledge and science-related skills were below average, so they were only classified as "nominally literate." There was a gap between awareness and action, and the practical application of environmental education was limited. The authors concluded that improved in-service teacher education and curriculum revision are needed to equip teachers with the competencies and commitment required for effective EE. Also, a study by Özdil and Çelik (2022) concluded that teachers had sufficient environmental attitudes, and insufficient level of knowledge about environmental issues.

The research problem for this study arises from the fact that no similar studies have been conducted in Slovenia or internationally, leaving the level of EL among chemistry teachers, specifically in the context of hydrosphere pollution, unknown. EE promotes environmental values, fosters positive attitudes, and encourages pro-environmental behaviours in learners (Wals et al., 2014). As environmental chemistry is an integral part of EE, chemistry teachers play a crucial role in engaging students with environmental content (Burmeister et al., 2012; Wan et al., 2023). Water-related education programs have been shown to enhance students' knowledge, perceptions, and motivation to engage with sustainability topics, leading to meaningful gains in EL (Del Rey et al., 2022). Achieving these outcomes requires not only the transmission of scientific knowledge but also the cultivation of relevant skills, attitudes, and behaviours (Amahmid et al., 2019). However, to achieve such results, chemistry teachers must first develop a high level of EL and personal awareness.

This study aimed to assess the EL of Slovenian chemistry teachers in the context of hydrosphere pollution, using the Hollweg model of EL (Hollweg et al., 2011), and to examine whether differences in EL are associated with teachers' participation in in-service education programmes, the educational level at which they teach, their age, and their teaching experience.

Guided by this aim, the study addressed the following research questions:

RQ1 How do chemistry teachers perceive the specific hydrosphere pollution issues?

RQ2 What is the level of environmental literacy among Slovenian chemistry teachers in the context of hydrosphere pollution?

RQ3 Are there any significant differences in chemistry teachers' environmental literacy based on their knowledge, competencies, dispositions, and behaviour?

RQ4 Are there any significant differences in chemistry teachers' environmental literacy whether they participated in in-service teacher education programmes on hydrosphere pollution?

RQ5 Are there any significant differences between lower and upper secondary chemistry teachers in their environmental literacy?

RQ6 What is the relationship between demographic variables (age and years of teaching chemistry) and the individual dimensions of EL?

METHODOLOGY

The study employs a quantitative research approach using descriptive and non-experimental methods.

Participants

66 chemistry teachers from Slovenia participated in this study. Their age ranged from 23 to 64 years with an average of 42.9 years (SD = 12.3 years). Their experience in teaching chemistry ranged from "teaching first year" to 39 years with the average 14.8 years (SD = 11.8 years). Additional demographic characteristics of the participants are presented in **Table 1**. The participation in this study was voluntary and anonymous. The Ethics Commission of the Faculty of Education, University of

Table 1. Demographic characteristics of the participating chemistry teachers

Variable	Description	Frequency	Percentage
Gender	Male	13	20
	Female	53	80
Type of school	Lower secondary	45	68
	Upper secondary	17	26
	Not teaching chemistry	4	6
In-service education on hydrosphere pollution issues	Yes	25	38
	No	41	62

Ljubljana, reviewed and approved this study (No. 13/2023) on August 25, 2023.

Instrument

An online instrument which was a combination of questionnaire and knowledge test was used for this study. It was developed specifically for the purpose of evaluating teachers' EL in the context of hydrosphere pollution and was based on the framework for assessing EL proposed by Hollweg et al. (2011). The instrument consisted of five parts:

(1) Demographics (5 items),

(2) Environmental competencies,

(3) Dispositions toward the environment,

(4) Environmentally responsible behaviour, and

(5) Environmental knowledge.

The contexts chosen for this study included current hydrosphere pollution issues: Agriculture pollution, ocean acidification, microplastics in water, e-waste pollution because of new technologies, and persistent organic pollutants. Individual tasks (from the topic of agriculture pollution) from different sections of the instrument are shown in **Figures 2** and **3** to provide readers with an overview of its appearance. For the readers that are interested, the instrument can be sent upon request by the corresponding author.

Environmental competencies

For each pollution issue, participants answered three open-ended questions supported by a schematic representation (see **Figure 2**), where they identified the issue, analysed it, and proposed solutions at different levels. Each part also included 3 additional items (15 total), where participants used a 5-point Likert scale to rate their interest in each environmental issue, its perceived severity, and the importance of discussing it in school.

Dispositions and environmentally responsible behaviour

This section of the instrument included 21 items: 13 on dispositions and 8 on self-reported ERB, each rated on a 5-point Likert scale (agreement or frequency). Nine items were adapted from Yavetz et al. (2009), three items were adapted from Milfont and Duckitt (2010), and eight items were newly created to address the specific focus of the questionnaire on hydrosphere pollution. Due to skewed (ceiling) responses, reliability was estimated using ordinal alpha from the polychoric correlation matrix (Chalmers, 2018), yielding values of 0.87 for dispositions and 0.62 for ERB.

Environmental knowledge

Teachers' knowledge was assessed with 15 four-tier tasks (three per issue). Each task included:

(1) A multiple-choice question,

(2) A 6-point Likert scale to indicate confidence in the answer,

(3) A multiple-choice explanation for the selected answer in the first tier, and

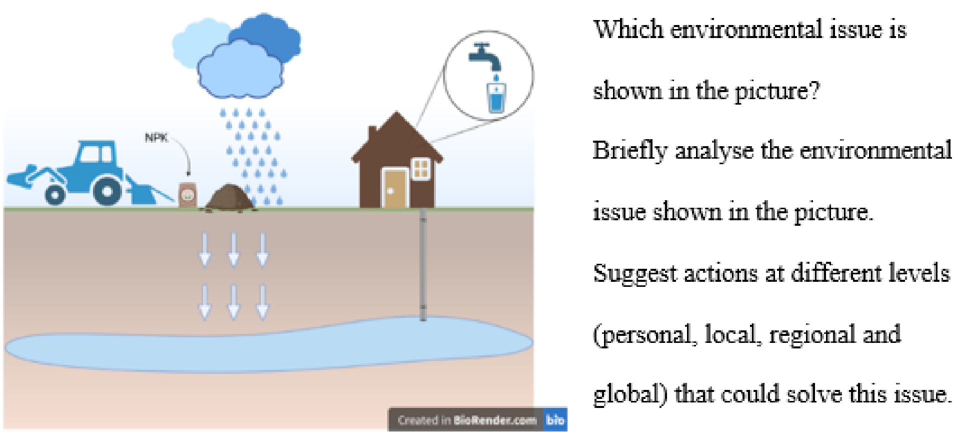

Figure 2. Example of an environmental issue scheme from the environmental literacy instrument (Source: Authors' own elaboration)

1.1 What ions are most commonly found in artificial fertilizers?

A K^+, NO_3^-, NH_4^+, PO_4^{3-}

B K^+, NO_3^-, PO_4^{3-}

C NO_3^-, PO_4^{3-}, NH_4^+, Ca^{2+}

D K^+, NO_3^-, NH_4^+, PO_4^{3-}, Cu^{2+}

1.2 How sure are you that you have chosen the right answer?

1	2	3	4	5	6
Just guessing	*Unsure*	*Quite sure*	*Sure*	*Very sure*	*Absolutely sure*

1.3 Why did you choose this answer under 1.1?

A In NPK fertilizers, nitrogen is present only in the form of nitrate ions, as ammonium ions are toxic to plants.

B Calcium ions give plants stem strength.

C Copper ions are present in all artificial fertilizers, as they enable the formation of chlorophyll and seeds in plants.

D The letter N in NPK fertilizers represents nitrogen in the form of nitrate and ammonium ions.

1.4 How sure are you that you have chosen the right answer?

1	2	3	4	5	6
Just guessing	*Unsure*	*Quite sure*	*Sure*	*Very sure*	*Absolutely sure*

Figure 3. Four-tier task example (Source: Authors' own elaboration)

Table 2. Criteria for categorizing teachers into groups based on their competencies, dispositions, behaviour, and knowledge

Grouping criteria	Group
< M – SD	Low level of competencies/dispositions/behaviour/knowledge
< M ± SD >	Middle level of competencies/dispositions/behaviour/knowledge
> M + SD	High level of competencies/dispositions/behaviour/knowledge

(4) A confidence rating for the explanation (see **Figure 3**).

The tasks assessed teachers' general knowledge of hydrosphere pollutants, their effects on organisms, and potential solutions. The maximum possible score was 30 points, which was used to calculate teachers' average achievement. In addition, knowledge levels for each task were evaluated using the criteria proposed by Gurel et al. (2015).

Research Design

The study was carried out in the academic year 2023/24, beginning with a literature review to identify a suitable EL assessment model, followed by the development and piloting of the instrument. Three experts in chemistry education and environmental chemistry reviewed and validated the first version of the instrument. It was then piloted with 20 pre-service chemistry teachers. In the competencies section students' answers on the open-ended questions were analysed to verify whether they measured the intended competencies. In the knowledge test, students completed tasks consisting of multiple-choice questions followed by open-ended items in which they were asked to explain their choices. Their responses were analysed and used to develop a third-tier set of multiple-choice questions, where participants in the main study later selected the correct explanation for their initial answer. The dispositions and ERB sections were piloted with 75 pre-service elementary teachers, as more students were enrolled in this programme. The competencies and knowledge test were not piloted with this group as it was assumed they did not have sufficient content knowledge for their answers to help validate those parts of the instrument. After the first pilot testing, some adaptations were made, and the final version of the instrument was reviewed again by three experts in chemistry education and environmental chemistry. Following revisions, the instrument was transferred to an online format and distributed via email to chemistry teachers in two phases due to initially low response rates. A total of 473 teachers (337 lower secondary and 136 upper secondary) were contacted, selected randomly based on publicly available email addresses. In the end, 66 teachers completed the instrument (14% response rate).

Data Analysis

The data collected with the on-line instrument were transferred to Excel and statistical analysis was carried out using SPSS Statistics Data Editor software (IBM SPSS Statistics Version 28.0.0.0). According to the results obtained in the questionnaires assessing teachers' competencies, dispositions, ERB, and knowledge, teachers were divided into three groups for each element according to the criteria shown in **Table 2**.

These groups of teachers were used to determine if there were any differences in their levels of EL based on their knowledge, dispositions, ERB, and competencies.

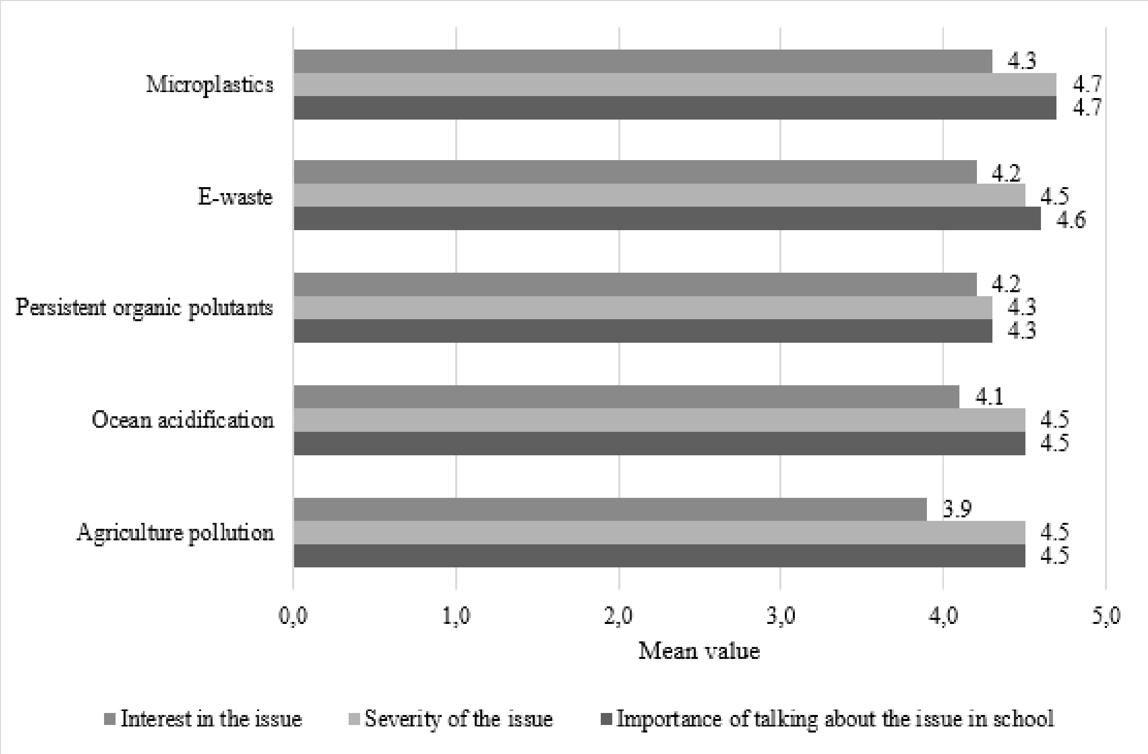

Figure 4. Teachers' perception of the addressed hydrosphere pollution issues (Source: Authors' own elaboration)

Kolmogorov-Smirnov test was used to identify the normality of data distribution. T-test and one-way ANOVA were used for normal data distribution, and Mann Whitney U-test, and Kruskal-Wallis test for non-normal data distribution. The correlation between the variables was analysed with Kendall's tau-b correlation coefficient. Dispositions and ERB questionnaires were validated in R using the psych package. Internal consistency was estimated as Cronbach's alpha from polychoric (ordinal) correlation matrices.

The overall environmental literacy score was calculated as the arithmetic mean of the four dimensions, each weighted equally (25%), giving a composite score expressed on a 0–100%.

RESULTS

Teachers' Perceptions of the Addressed Hydrosphere Pollution Issues

Results in **Figure 4** show that teachers expressed strong interest in hydrosphere issues, especially microplastics, which they rated most important, while agriculture pollution was rated least important. Similar results were obtained in relation to participants' assessment of the severity of environmental problems and the importance of discussing them at school. In both cases, microplastics had the highest average value. The lowest average value for both items was for persistent organic pollutants.

Teachers' Environmental Literacy

With the mean value of only 66.2% (SD = 8.0%) results suggest that teachers have insufficient EL in the context of hydrosphere pollution. However, to adequately assess teachers' level of EL, it is necessary to look at their scores on the individual dimensions of literacy. **Figure 5** shows teachers' average scores on each part of the instrument and their average total score indicating their level of EL.

Knowledge

In-service teachers' main achievement scores are shown in **Figure 5**. with the mean percentage points which present the sum of all correct answers. The results show that the overall mean score was moderately low (57.4%) with the standard deviation of 13.0% indicating very limited knowledge. However, the four-tier tasks which were used in the knowledge test made it possible to identify the level of knowledge for each task more specifically therefore allowing to find out which topics are not familiar to the teachers.

As shown in **Table 3**, most teachers demonstrated lack of knowledge across tasks, particularly with persistent organic pollutants and e-waste. Misconceptions were common for ocean acidification and microplastics. Most teachers were found to have a "scientific concept" level of knowledge in the task related to the impact of microplastics on aquatic organisms followed by the task related to treating contaminated water (due to artificial fertilizers) at home.

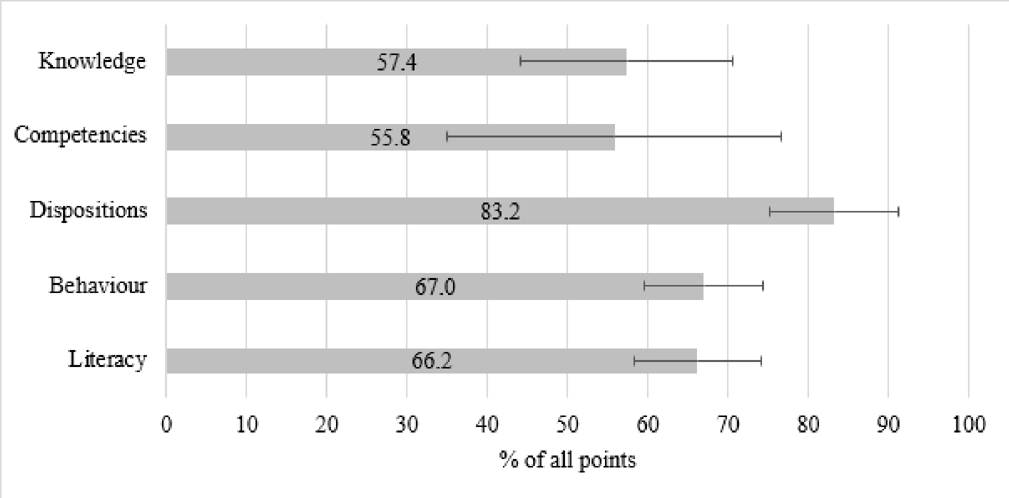

Figure 5. Average score on the dimensions of environmental literacy (Source: Authors' own elaboration)

Table 3. Level of knowledge demonstrated by chemistry teachers for each diagnostic task on hydrosphere pollution issues

Topic	Task	Task description	Level of knowledge (f%)				
			SC	LK	FP	FN	MSC
Agriculture pollution	1	Ions present in artificial fertilizers.	30	**53**	0	5	12
	2	Treatment of polluted water (due to artificial fertilizers) at home.	35	**60**	0	0	5
	3	Process of transforming ammonia ions in wastewater via bacteria.	6	**80**	8	3	3
Ocean acidification	4	Understanding the mechanism of ocean acidification.	32	**54**	2	3	9
	5	Ways of resolving ocean acidification.	2	**74**	2	0	22
	6	Effects of ocean acidification on organisms.	20	**66**	4	2	8
Microplastics	7	Definition of microplastics.	20	**51**	11	0	18
	8	Impact of microplastics on sea organisms.	41	**44**	4	2	9
	9	Method of removing microplastics from water.	12	**77**	2	0	9
E-waste	10	Properties of e-waste.	15	**68**	0	14	3
	11	Method of removing heavy metals from the environment.	14	**80**	0	0	6
	12	Effect of heavy metals on organisms.	9	**70**	4	6	11
Persistent organic pollutants	13	Definition of persistent organic pollutants.	2	**81**	3	5	9
	14	Impact of persistent organic pollutants on water organisms.	9	**86**	0	0	5
	15	Method of removing persistent organic pollutants from water.	4	**94**	0	0	2

*SC = scientific conception, LK = lack of knowledge, FP = false positive knowledge, FN = false negative knowledge, MSC = misconceptions

Competencies

Results show that on average teachers scored moderately low (M = 55.8%) on this variable with quite a substantial standard deviation of 21% indicating very varying competencies among them. Open-ended questions were scored on a three-point scale (0 = insufficient, 1 = partly sufficient, 2 = sufficient). The responses were graded independently by two assessors. In cases where there were differences in the assessment of the teachers' responses, the assessors reached a consensus. The scoring example for agriculture pollution is shown in **Table 4**. Most teachers correctly identified agricultural pollution (59.1%), followed by microplastics (54.5%), while ocean acidification was the least accurately identified (40.9% incorrect). When asked to analyse the provided issues, analysis of agricultural pollution was most accurate (51.5%), followed by microplastics (40.9%), with ocean acidification again showing the highest rate of incorrect responses (40.9%). In suggesting solutions, agricultural pollution elicited the most appropriate answers (37.9%), followed by microplastics (33.3%), while e-waste had the highest proportion of incorrect solutions (33.3%).

Dispositions

The results show teachers have quite positive dispositions towards the environment (M = 83.2%, SD = 8.1%). They have strong pro-environmental values and emotional connections to water resources. They almost unanimously appreciate the quality of Slovenian tap water (98.5%), feel emotionally affected by water pollution (94.0%), support corporate financial responsibility for pollution prevention (95.5%) and are in favour of increasing government funding for research in this area (94.0%). Teachers also show a high level of self-efficacy when it comes to influencing their family/friends' attitudes towards water conservation (95.5%) and are overwhelmingly in favour of dedicating

Table 4. Open-ended questions scoring example

Task	Sufficient	Partly sufficient	Insufficient
Which environmental issue is shown in the picture?	Groundwater pollution caused by excessive use of artificial fertilizers.	Groundwater pollution.	Eutrophication, phosphate and nitrate pollution.
Briefly analyse the environmental issue shown in the picture.	Due to the excessive use of artificial fertilizers, rainfall causes the dissolution and leaching of their components (nitrate, phosphate, and ammonium salts) into the groundwater, which serves as a source of drinking water. If this water is consumed, it can lead to various health problems.	Soil, which acts as a natural filter, is becoming increasingly polluted. The pollutants then leach into the groundwater, which serves as a source of drinking water.	The problem is present in certain areas of Slovenia. The issue is that small farmers are insufficiently monitored.
Suggest actions at different levels (personal, local, regional and global) that could solve this issue.	**Personal level:** use of various types of natural fertilizers; choosing the appropriate time for fertilization; considering the amount of natural fertilizer used in relation to the size of the area being fertilized. **Local level:** municipalities could provide additional subsidies to farmers who use natural fertilizers and follow the guidelines of organic farming, which excludes the use of artificial fertilizers and pesticides. **Regional level:** ensuring that the local level receives adequate financial resources to promote organic farming; monitoring to ensure that the local level truly follows the guidelines of organic farming. **Global level:** proposing high-quality guidelines for organic farming; appropriately and effectively raising public awareness about pressing environmental issues; ensuring that the population maintains a comprehensive understanding of the environmental problem.	Fertilizing at an appropriate time, supporting small farms, prior soil analysis followed by more specific and appropriate fertilization.	Prohibition or restriction of fertilizer use.

more school hours to the topic of water pollution (90.9%). Furthermore, teachers show a realistic scepticism towards technological solutions: 77.3% reject the idea that science alone can solve water pollution, implicitly recognising the need for societal and behavioural change. A somewhat more concerning distribution of responses (74.3%) suggests that most respondents view water cleanliness from a personal benefit perspective rather than from an environmental and wildlife protection standpoint. It can also be observed that there is a discrepancy between teachers' knowledge and behaviour, with only 57.5% believing that more personal knowledge would lead to more environmentally friendly behaviour, despite being strongly in favour of expanded environmental education.

Environmentally responsible behaviour

The results indicate a mixed pattern in teachers' self-reported ERB (M = 67.0%; SD = 7.4%). Encouragingly, nearly all respondents state that they save water in daily life (98.5%), and a vast majority dispose of hazardous waste like batteries and electronics properly (89.5%). Behaviours requiring more public engagement or systemic action, such as participating in clean-up campaigns (28.8%) or taking part in water-related protests or petitions (15.2%) are far less frequent, indicating possible barriers such as time, perceived impact, or social norms. When it comes to potentially harmful behaviours, teachers prove to be responsible. For example, 80.4% never or rarely throw used plastic packaging into mixed waste bins, also 87.9% never or rarely pour used cooking oil down the drain. The low reported use of artificial fertilizers (9.1%) suggests awareness of their environmentally harmful effects. Finally, the low proportion of teachers who regularly use bicycles or public transport (19.7%) may reflect logistical challenges but also highlights an opportunity for improvement in promoting sustainable mobility habits.

Differences in the Level of Environmental Literacy Based on Teachers' Knowledge, Competencies, Dispositions, and ERB

Knowledge

When comparing teachers with different level of knowledge, independent samples Kruskal-Wallis test showed statistically significant differences in their level of EL ($H(2) = 24.731$, $p < .001$) with a large effect size ($\eta 2 = .399$). Dunn's test with Bonferroni corrections was used for the pairwise multiple comparison. As shown in **Figure 6** the test showed significant differences between groups with low and medium level of knowledge and between groups with low and high level of knowledge.

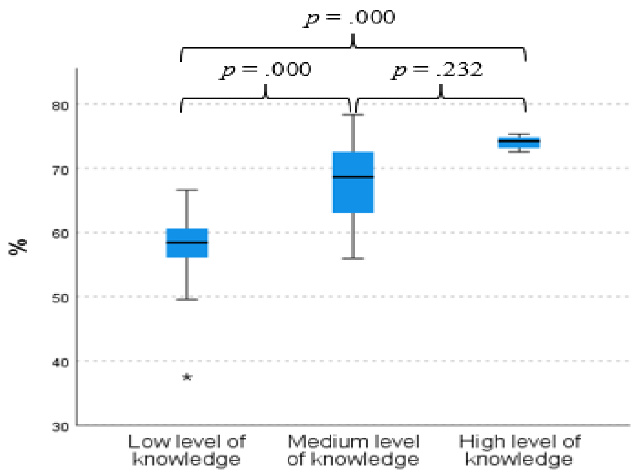

Figure 6. Teachers' environmental literacy based on their level of knowledge (Source: Authors' own elaboration)

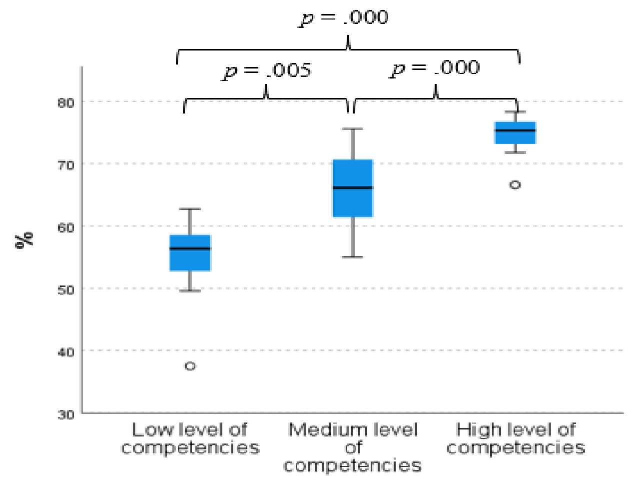

Figure 7. Teachers' environmental literacy based on their level of competencies (Source: Authors' own elaboration)

Teachers with higher level knowledge about the presented hydrosphere pollution issues are more environmentally literate than those with less knowledge.

Competencies

When comparing teachers with different level of environmental competencies, independent samples Kruskal-Wallis test showed statistically significant differences in their level of EL ($H(2) = 30.441$, $p < .001$) with a large effect size ($\eta2 = .498$). Dunn's test with Bonferroni corrections was used for the pairwise multiple comparison. As shown in **Figure 7** the test showed significant differences between all groups. Teachers with higher level of competencies tend to be more environmentally literate.

Dispositions and ERB

When comparing teachers with different dispositions, one-way ANOVA showed statistically significant differences in their level of EL ($F(2,57) = 3.660$, $p = .032$) with a large effect size ($\eta2 = .114$). A shown in

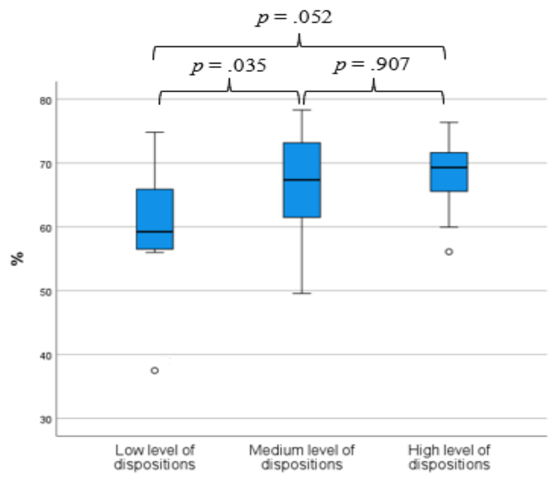

Figure 8. Teachers' environmental literacy based on their dispositions (Source: Authors' own elaboration)

Figure 8 Tukey post-hoc test showed significant differences only between groups with low and medium level of dispositions.

When comparing groups of teachers with different levels of ERB. One-way ANOVA showed no statistically significant differences in their level of EL ($F(2,57) = 1.994$, $p = .146$).

Differences in Teachers' Environmental Literacy by In-Service Teacher Education Participation

When comparing teachers who had participated in in-service education on hydrosphere pollution with those who had not, no statistically significant differences were found in their overall level of EL ($U = 342.5$, $p = .367$). Similar non-significant results were observed for knowledge ($U = 366.5$, $p = .597$), dispositions ($U = 461.5$, $p = .499$), and competencies ($t = 1.746$, $df = 64$, $p = .086$). However, a statistically significant difference emerged in self-reported ERB ($t = -2.009$, $df = 64$, $p = .049$) with a medium effect size ($d = 0.51$). Teachers who participated in in-service education achieved a higher ERB score ($M = 69.3\%$; SD 6.7%) than those who had not ($M = 65.6\%$; $SD = 7.5\%$). It can be concluded that there are statistically significant differences in teachers' behaviour depending on their participation in in-service education. However, no statistically significant differences were found regarding the other EL dimensions. A limitation of this analysis is the lack of information about the content of the in-service education programmes attended by some teachers.

Differences in Teachers' Environmental Literacy by Level of Education Where Teachers Teach

When comparing teachers who teach chemistry in lower secondary and upper secondary school, no statistically significant differences were found in their overall level of EL ($t = 1.786$, $df = 54$, $p = .080$). Similar non-significant results were obtained for the individual

Table 5. Correlations between demographic variables (age and years of teaching chemistry) and individual dimensions of environmental literacy

Variables	Dispositions	Behaviour	Competencies	Knowledge
Age	-.108	.147	-.349**	-.060
Years of teaching	-.037	.189*	-.211*	.050
Dispositions	–	-.147	.107	-.048
Behaviour	–	–	-.011	.012
Competencies	–	–	–	.233*
Knowledge	–	–	–	–

* $p < .05$; ** $p < .001$

EL dimensions: knowledge (U = 331.0, p = .993), dispositions (t = 1.915, df = 22.4, p = .068), ERB (U = 334.0, p = .441) and competencies (t = 1.883, df = 60, p = .064). It can be concluded that no statistically significant differences in chemistry teachers' level of EL or its dimensions were found between upper and lower secondary school teachers.

Relationship Between Age and Years of Teaching Chemistry and the Individual Dimensions of Teachers' Level of Environmental Literacy

Kendall's tau-b correlation coefficient was used to determine the relationships among teachers' age, their years of teaching chemistry and the individual dimensions of EL.

As shown in **Table 5** the results reveal a strong negative correlation between age and environmental competencies, and a moderate negative correlation between years of teaching and competencies. In contrast, a weak but statistically significant positive correlation was observed between years of teaching and behaviour. Among the dimensions of EL, only a moderate positive correlation was found between knowledge and competencies.

DISCUSSION

This study provides important insights into the current state of EL among Slovenian chemistry teachers, particularly concerning hydrosphere pollution issues such as microplastics, ocean acidification, agriculture pollution, e-waste, and persistent organic pollutants.

Teachers' Perceptions of the Presented Hydrosphere Pollution Issues

In general, chemistry teachers show interest in the addressed hydrosphere pollution issues, they think these topics are important and that it is urgent to discuss them in school. Microplastic pollution of water was the one that attracted the most interest and was rated as the most severe and the most important to discuss in school. This could be since microplastics pollution, is a more up to date and widely discussed topic in the media in comparison to others.

Teachers' Environmental Literacy

The overall EL score was below the 70% benchmark (Coyle, 2005; Tuncer et al., 2009), highlighting a gap between positive dispositions and insufficient knowledge and competencies. Similar trends were reported by Garcia and Cobar-Garcia (2022) and Özdil and Çelik (2022), where teachers demonstrated positive attitudes but limited environmental knowledge.

Environmental knowledge is a core component of EL, as it underpins informed decision-making and responsible environmental action (Liu et al., 2015). In this study teachers showed insufficient knowledge with notable gaps in understanding emerging issues such as persistent organic pollutants and e-waste. The results in both cases are not so surprising, as these are relatively new environmental issues which have not yet been as widely publicly addressed and discussed as others in Slovenia, but younger teachers had the opportunity to study these topics at environmental chemistry university course. Teachers showed greater familiarity with agricultural pollution and microplastics. Slovenia has many agricultural areas and, consequently, there is much discussion about the impacts of agriculture on the environment. Microplastics, on the other hand, are currently one of the most widely discussed environmental issues, frequently appearing in the media and popular science journals. Nonetheless, misconceptions were present even in these areas, underscoring the need for targeted knowledge development across all five environmental topics.

Similar findings have been reported elsewhere. In the study from Özdil and Çelik (2022), all groups of teachers demonstrated insufficient knowledge about environmental issues. The results of a study by Liu et al. (2015) show that, on average, teachers from different school levels in Taiwan had moderate environmental knowledge. Michail et al. (2007) found that Greek primary school teachers had several knowledge gaps and misconceptions about environmental issues (acid rain, ozone layer depletion and the greenhouse effect). Gkargkavouzi et al. (2018) found that while teachers are well informed about climate change, renewable natural resources and the definition of biodiversity, their knowledge of the greenhouse effect is very low, indicating moderate to low environmental knowledge. The results also show that teachers with better knowledge have a statistically significant higher level of EL. According to the findings by Bloom and Fuentes (2019) teachers' environmental content knowledge can be improved with targeted professional development based on experiential learning.

The level of teachers' competencies varied greatly among respondents, with many providing only partial or insufficient responses to scenario-based items. Teachers struggled to propose adequate solutions, especially for more complex issues like e-waste and ocean acidification. This finding suggests that fostering competencies requires both content knowledge and experience with real-world environmental challenges. The results also show that teachers with better competencies have a statistically significant higher level of EL. Similar results were obtained by Garcia and Cobar-Garcia (2018) where teachers also lacked appropriate skills in identifying environmental issues and ability to problematize the issues as well as analysing probable consequences and factors contributing to a given issue and proposing most fitting solutions for the given issues.

Positive dispositions toward the environment were widespread among participating teachers, yet their effect on overall EL was limited. Significant differences were found only between teachers with low and medium disposition scores, suggesting that strong environmental attitudes alone do not guarantee higher literacy without corresponding knowledge and competencies. Similar findings were reported by Garcia and Cobar-Garcia (2022).

Similarly, self-reported ERB was moderate, with frequent engagement in household-level actions but limited participation in collective initiatives. No significant differences in EL emerged between groups with differing ERB levels, indicating that responsible behaviours may develop independently from the analytical skills and content knowledge central to EL. These findings align with previous studies (Liu et al., 2015; Öztürk & Pizmony-Levy, 2025), which emphasise that attitudes and behaviours, while essential for fostering environmental engagement, must be complemented by targeted professional development aimed at strengthening teachers' conceptual understanding and problem-solving competencies to translate dispositions into effective classroom practice.

Differences in EL According to In-Service Teacher Education and School Type Where Teachers Teach

Contrary to expectations, there were no statistically significant differences in teachers' EL or its dimensions according to in-service teacher education participation, apart from the self-reported ERB, where teachers who participated in in-service education programs expressed statistically significant higher self-reported ERB scores. It appears that in-service teacher education contributes to more environmentally conscious behaviour. While these results are consistent with the study from Kidman and Casinader (2018) where impact of general in-service teacher education also appeared to be limited, it raises questions about the relevance and quality of such educational programs. One possible explanation is that the content of in-service education programs may not sufficiently address hydrosphere issues or engage teachers in a meaningful way. Garcia and Cobar-Garcia (2022) on the other hand highly recommend in-service teacher education as they believe it enhances teachers' environmental knowledge and competencies.

Similarly, no significant differences were found between lower and upper secondary school teachers, suggesting that differences in curriculum do not necessarily lead to measurable differences in their EL. These results are quite surprising as upper secondary teachers teach more topics that may include hydrosphere pollution issues addressed in this study and should therefore have higher EL level than lower secondary teachers. Similar findings were obtained by Garcia and Cobar-Garcia (2022) who found no differences in EL between elementary and secondary school teachers.

Relationship Between Age, Years of Teaching Chemistry and the Individual Dimensions of EL

The strong negative correlation between age and environmental competencies, along with a moderate negative correlation between years of teaching and competencies, suggests that younger teachers, who also have fewer years of teaching experience, tend to exhibit higher levels of environmental competencies. Over the past 10–15 years, pre-service chemistry teachers have enrolled in an environmental chemistry course that addresses several of the environmental issues examined in this study, which may have contributed to their higher competency levels. In contrast, a weak but statistically significant positive correlation was observed between years of teaching and ERB, indicating that more experienced teachers are somewhat more likely to demonstrate positive ERB. Among the dimensions of EL, only a moderate positive correlation emerged between knowledge and competencies, suggesting that teachers with greater environmental knowledge also tend to possess stronger environmental competencies. Similarly, García and Cobar-García (2018) found that knowledge was a positive predictor of elementary teachers' environmental competencies.

CONCLUSIONS

This study provides a comprehensive assessment of Slovenian chemistry teachers' EL in the context of hydrosphere pollution. The results show that although teachers exhibit positive environmental dispositions, such as concern about water pollution and support for nature conservation policies, their knowledge and competencies regarding important environmental issues (e.g. microplastics, e-waste, persistent organic pollutants) as well as their ERB are insufficient. The overall EL score indicates a critical gap between positive attitudes and the ability to take effective environmental action. Of the five topics covered, teachers were most familiar and engaged with microplastics and agricultural pollution, likely due to greater public awareness and relevance to the Slovenian context. However, even within these domains, misconceptions were widespread. Topics such as ocean acidification and persistent organic pollutants were poorly understood and least successfully analysed or addressed by teachers. Statistical analyses showed no significant differences in teachers' EL based on their participation in in-service teacher education programs and the school level at which teachers teach (lower vs. upper secondary) which is raising concerns about the relevance and impact of current professional development programmes. However, the results also showed a negative correlation between age and competencies, suggesting that younger teachers are generally better able to identify, analyse, and propose solutions to environmental problems, indicating that students have acquired these competencies in recent years during their studies. Nevertheless, this research indicates the need to strengthen chemistry teachers' EL. This could be achieved by embedding hydrosphere pollution topics more clearly in the curriculum, and by developing more targeted, content-specific in-service teacher education programmes, that focus on both conceptual understanding and real-world application, ensuring that positive attitudes are reinforced with solid knowledge and actionable competencies. Such improvements are essential to enable chemistry educators to more effectively contribute to environmental education and help students to become environmentally literate citizens.

LIMITATIONS

A key limitation is the small sample size, partly due to limited access to teacher emails and the length of the questionnaire (40 minutes). Another limitation is that some measurements relied on teachers' self-assessment, which is susceptible to social desirability bias and inaccurate self-reporting. Additionally, conclusions regarding teachers' EL based on their participation in in-service education programmes should be treated with caution, as they did not provide specific information about the content, duration or timing of their participation in such programmes.

IMPLICATIONS FOR EDUCATION

Topics on water pollution are not obligatory in the current Slovenian chemistry curricula at the lower secondary education. In upper secondary education, the situation is similar, with these topics being most widely covered in the curricula for vocational school. In lower secondary school they are part of the elective course "Environmental chemistry" and could be very important contexts for applying chemistry concepts from the curriculum (such as acid and bases; hydrocarbons, polymers). The upper secondary school curriculum offers more options for cross-curricular integration (such as acid and bases; hydrocarbons, halogenated hydrocarbons, oxygen and nitrogen containing organic compounds, polymers…) but in the end, it is up to the teachers to decide which of these issues they will address in their lessons. Since teachers, despite their limited knowledge of the issues discussed, show interest in addressing them in school, it would be reasonable to create a handbook that is accessible to all teachers. This handbook should provide a simple explanation of these issues and suggestions for activities that would help teachers bring these topics closer to their students. It would also be beneficial to organize more targeted professional development sessions for teachers, which would address water pollution problems through concrete examples and proposals for specific activities and then measure the effect of such professional development on teachers' EL.

FUTURE RESEARCH

It would be reasonable to expand the study to include other spheres (pedosphere and atmosphere) to gain a more comprehensive insight into the environmental literacy of chemistry teachers. The study could also be repeated in other countries to compare the EL of teachers across different nations. Additionally, the study could also be extended to measure the effect of in-service professional education programmes on teachers' EL by organising such sessions for them.

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REFERENCES

Amahmid, O., El Guamri, Y., Yazidi, M., Razoki, B., Kaid Rassou, K., Rakibi, Y., Knini, G., & El Ouardi, T. (2019). Water education in school curricula: Impact on children knowledge, attitudes and behaviours towards water use. *International Research in Geographical and Environmental Education, 28*(3), 178-193. https://doi.org/10.1080/10382046.2018.1513446

Bloom, M., & Fuentes, S. Q. (2019). Experiential learning for enhancing environmental literacy regarding energy: A professional development program for inservice science teachers. *Eurasia Journal of Mathematics, Science and Technology Education, 15*(6), Article em1699. https://doi.org/10.29333/ejmste/103571

Burmeister, M., Rauch, F., & Eilks, I. (2012). Education for sustainable development (ESD) and chemistry education. *Chemistry Education Research and Practice, 13*(2), 59-68. https://doi.org/10.1039/C1RP90060A

Chalmers, R. P. (2018). On misconceptions and the limited usefulness of ordinal alpha. *Educational and Psychological Measurement, 78*(6), 1056-1071. https://doi.org/10.1177/0013164417727036

Coyle, K. (2005). *Environmental literacy in America: What ten years of NEETF/Roper research and related studies say about environmental literacy in the US*. National Environmental Education & Training Foundation.

Del Rey, R., Ojeda, M., Mora-Merchán, J. A., Nieves Sánchez-Díaz, M., Morgado, B., & Lasaga, M. J. (2022). Environmental education: Effects on knowledge, attitudes and perceptions, and gender differences. *International Research in Geographical and Environmental Education, 31*(4), 282-303. https://doi.org/10.1080/10382046.2021.1977004

Disinger, J. F., & Roth, C. E. (1992). *Environmental literacy*. ERIC/CSMEE Digest.

Dogan, Y., Simsar, A., & Konca, A. S. (2025). Preservice teachers' perceptions of environmental issues. *Journal of Baltic Science Education, 24*(3), 399-412. https://doi.org/10.33225/jbse/25.24.399

Garcesa, R. D., & Limjuco, R. P. (2014). Environmental literacy and integration of environment issues among science teachers in region XI: Basis for training design. *UIC Research Journal, 20*(1), 187-205.

Garcia, M. N. Z., & Cobar-Garcia, M. R. V. (2018). The environmental literacy of elementary school teachers based in the city of Manila and Nueva Ecija province. *Journal of Nature Studies, 17*(2), 10-29.

Garcia, M. N. Z., & Cobar-Garcia, M. R. V. (2022). The environmental literacy of elementary and high school teachers based in Manila and Nueva Ecija province: A mixed methods study. *Environment, Development and Sustainability, 24*(5), 6878-6902. https://doi.org/10.1007/s10668-021-01732-2

Gkargkavouzi, A., Halkos, G., & Matsiori, S. (2018). *Teachers' environmental knowledge and pro-environmental behaviour: An application of CNS and EID scales* (MPRA Paper No. 84505). University Library of Munich.

Gurel, D. K., Eryılmaz, A., & McDermott, L. C. (2015). A review and comparison of diagnostic instruments to identify students' misconceptions in science. *Eurasia Journal of Mathematics, Science & Technology Education, 11*(5), 989-1008. https://doi.org/10.12973/eurasia.2015.1369a

Hollweg, K. S., Taylor, J. R., Bybee, R. W., Marcinkowski, T. J., McBeth, W. C., & Zoido, P. (2011). *Developing a framework for assessing environmental literacy*. North American Association for Environmental Education.

Husamah, H., Suwono, H., Nur, H., & Dharmawan, A. (2022). The development and validation of environmental literacy instrument based on spirituality for prospective science teachers. *Eurasia Journal of Mathematics, Science and Technology Education, 18*(12), Article em2206. https://doi.org/10.29333/ejmste/12732

Intergovernmental Panel on Climate Change. (2021). Climate Change 2021: The Physical Science Basis. *Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press.

Kaya, V. H., & Elster, D. (2019). A critical consideration of environmental literacy: Concepts, contexts, and competencies. *Sustainability, 11*(6), Article 1581. https://doi.org/10.3390/su11061581

Kidman, G., & Casinader, N. (2019). Developing teachers' environmental literacy through inquiry-based practices. *Eurasia Journal of Mathematics, Science and Technology Education, 15*(6), Article em1687. https://doi.org/10.29333/ejmste/103065

Liu, S.-Y., Yeh, S.-C., Liang, S.-W., Fang, W.-T., & Tsai, H.-M. (2015). A national investigation of teachers' environmental literacy as a reference for promoting environmental education in Taiwan. *The Journal of Environmental Education, 46*(2), 114-132. https://doi.org/10.1080/00958964.2014.999742

Maurer, M., & Bogner, F. X. (2020). Modelling environmental literacy with environmental knowledge, values and (reported) behaviour. *Studies in Educational Evaluation, 65*, Article 100863. https://doi.org/10.1016/j.stueduc.2020.100863

Michail, S., Stamou, A. G., & Stamou, G. P. (2007). Greek primary school teachers' understanding of current environmental issues: An exploration of their environmental knowledge and images of nature.

Science Education, *91*(2), 244-259. https://doi.org/10.1002/sce.20185

Milfont, T. L., & Duckitt, J. (2010). The environmental attitudes inventory: A valid and reliable measure to assess the structure of environmental attitudes. *Journal of Environmental Psychology*, *30*(1), 80-94. https://doi.org/10.1016/j.jenvp.2009.09.001

Özdil, E., & Çelik, A. Y. (2022). Environmental literacy: Comparison between chemistry teacher candidates, chemistry teachers, and individuals in environmentally related professions. *International Journal of Educational Research Review*, *7*(4), 366-379. https://doi.org/10.24331/ijere.1172688

Öztürk, M., & Pizmony-Levy, O. (2025). Motives for and predictors of teachers' adoption of pro-environmental behaviours. *Environmental Education Research*, *31*(3), 627-647. https://doi.org/10.1080/13504622.2024.2377367

Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., Biggs, R., Carpenter, S. R., de Vries, W., de Wit, C. A., Folke, C., Gerten, D., Heinke, J., Mace, G. M., Persson, L. M., Ramanathan, V., Reyers, B., & Sörlin, S. (2015). Planetary boundaries: Guiding human development on a changing planet. *Science*, *347*(6223). https://doi.org/10.1126/science.1259855

Szczytko, R., Stevenson, K., Peterson, M. N., Nietfeld, J., & Strnad, R. L. (2018). Development and validation of the environmental literacy instrument for adolescents. *Environmental Education Research*, *25*(2), 193-210. https://doi.org/10.1080/13504622.2018.1487035

UNESCO. (1978). *Intergovernmental Conference on Environmental Education, Tbilisi, USSR, 14–26 October 1977: Final report*. United Nations Educational, Scientific and Cultural Organization. https://unesdoc.unesco.org/ark:/48223/pf0000032763

United Nations. (n.d.) *The Sustainable development goals.* https://www.un.org/sustainabledevelopment/development-agenda/

Tilbury, D. (2011). *Education for sustainable development: An expert review of processes and learning.* UNESCO. https://unesdoc.unesco.org/ark:/48223/pf0000191442

Tuncer, G., Tekkaya, C., Sungur, S., Cakiroglu, J., Ertepinar, H., & Kaplowitz, M. (2009). Assessing pre-service teachers' environmental literacy in Turkey as a mean to develop teacher education programs. *International Journal of Educational Development*, *29*, 426-436. https://doi.org/10.1016/j.ijedudev.2008.10.003

Wals, A. E., Brody, M., Dillon, J., & Stevenson, R. B. (2014). Convergence between science and environmental education. *Science*, *344*(6184), 583-584. https://doi.org/10.1126/science.1250515

Wan, Y., Ding, X., & Yu, H. (2023). Pre-service chemistry teachers' understanding of knowledge related to climate change. *Chemistry Education Research and Practice*, *24*(4), 1219-1228. https://doi.org/10.1039/D3RP00024A

Yavetz, B., Goldman, D., & Pe'er, S. (2009). Environmental literacy of pre-service teachers in Israel: A comparison between students at the onset and end of their studies. *Environmental Education Research*, *15*(4), 393-415. https://doi.org/10.1080/13504620902928422

Yeh, F.-Y., Tran, N.-H., Hung, S. H., & Huang, C.-F. (2022). A study of environmental literacy, scientific performance, and environmental problem-solving. *International Journal of Science and Mathematics Education*, *20*, 1883-1905. https://doi.org/10.1007/s10763-021-10223-9