American Behavioral Scientist

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Journal:	*American Behavioral Scientist*
Manuscript ID	Draft
Manuscript Type:	Accepted Article
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Beyond the Illusion of Knowledge: Overconfidence and misconceptions in Science Teachers' Environmental Literacy and their Impact on Behavior

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Abstract

Environmental literacy is essential for understanding and effectively teaching the climate system. However, discrepancies between actual and self-perceived environmental literacy can influence science-based decision-making and pro-environmental behavior. This study examines the extent of this gap among secondary science teachers and its implications for environmental education. A survey was conducted with 433 secondary science teachers, assessing actual environmental literacy through a standardized test and self-perceived literacy via a Likert-scale questionnaire. Participants' pro-environmental behaviors were also analyzed to determine the influence of perceived and actual knowledge on their actions. Findings reveal a significant gap between actual and self-perceived environmental literacy. No direct relationship was found between beliefs about the environmental future and pro-environmental behavior.

In contrast, while self-perceived literacy strongly predicts pro-environmental behavior ($p < 0.01$), actual literacy does not show a significant correlation, suggesting that individuals may act on confidence rather than scientific understanding, thereby increasing susceptibility to misconceptions and misinformation. These results underscore the urgent need for specialized Earth System Science training for science teachers to bridge misconceptions, enhance critical thinking, and equip educators with the necessary tools to teach climate-related topics accurately. A holistic approach to environmental education that integrates scientific knowledge, values, and action is crucial for fostering evidence-based reasoning and empowering future generations to make informed environmental decisions in the face of global challenges.

Keywords: Environmental literacy; climate misconceptions; environmental beliefs; pro-environmental behavior; Earth System Science (ESS) education

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Introduction

Environmental literacy is defined as the set of knowledge, attitudes, and behaviors that enable individuals to understand environmental systems, make informed decisions, and act responsibly (Goulgouti et al., 2019). This concept is essential in education, particularly in climate change and sustainability teaching, as a solid understanding of environmental systems facilitates the adoption of pro-environmental behaviors (Díaz-Siefer et al., 2015). While some studies have found that higher environmental knowledge predicts more sustainable behavior (e.g., Dopelt et al., 2020), other research suggests that values and perceived knowledge may play a more central role. This ongoing debate highlights the need to examine the interplay between actual and self-perceived environmental literacy and their respective influence on pro-environmental action. Environmental literacy is structured into three main dimensions (Maurer & Bogner, 2020):

- Environmental knowledge: Understanding key principles about ecosystems, natural systems, and human-environment interactions.
- Environmental attitudes and values: The level of concern for environmental issues and the willingness to adopt sustainable lifestyles.
- Pro-environmental behaviors or ecological conduct: Concrete actions that reflect the application of environmental knowledge and values in daily life, such as reducing energy consumption, recycling, or using sustainable transportation.

The role of teachers in shaping environmental literacy is crucial, as their knowledge, beliefs, and scientific training directly influence how they teach these topics. Higher environmental literacy among educators not only enhances the delivery of key concepts and fosters pro-environmental attitudes in students but also correlates with improved academic performance (Nation & Feldman, 2021). A key strategy for strengthening environmental literacy in climate change education is the integration of Earth System Science (ESS), which examines the interactions between the atmosphere, biosphere, geosphere, and hydrosphere, providing a comprehensive framework for understanding environmental processes and climate change (Breslyn & McGinnis, 2019; Steffen et al., 2020; Ribeiro & Orion, 2021).

In this context, teachers' environmental literacy plays a vital role in fostering critical thinking, informed decision-making, and responsible environmental behavior—essential skills for addressing climate challenges (Monroe et al., 2013). This situation is particularly relevant in secondary education, where climate change is taught across disciplines, including science, geography, ethics, and economics (Liu et al., 2015). ESS education enhances students' ability to identify relationships between environmental components and analyze climate change on multiple levels (Roychoudhury et al., 2017). A systems-based approach to climate change is key to improving scientific literacy in Spanish-speaking countries and its integration into mandatory education is necessary to help students understand Earth's interconnected processes and analyze environmental challenges from a multidisciplinary perspective (Pascual Trillo, 2013). This approach would cultivate a deeper awareness of sustainability and the complexity of Earth’s systems, ultimately preparing future generations to tackle pressing environmental issues (Passow, 2022).

Self-perceived environmental literacy

Self-perceived environmental literacy refers to an individual's subjective assessment of their knowledge and understanding of environmental issues, which does not necessarily align with their actual level of environmental literacy. Studies indicate that individuals tend to overestimate their environmental knowledge, which can lead to misinformation and reduced engagement in sustainable practices (Mundt et al., 2024; Sarıbaş et al., 2014). Rosdiana et al. (2020) analyzed the relationship between self-efficacy and environmental literacy in students, finding that greater confidence in one's environmental knowledge did not necessarily correlate with a higher level of actual literacy. Furthermore, Bert et al. (2023) found that individuals who perceived themselves as having insufficient knowledge about environmental issues were less likely to verify information, making them more susceptible to spreading misinformation and less inclined to adopt pro-environmental behaviors.

Ultimately, the gap between perceived and actual environmental literacy poses a challenge for scientific education and the adoption of evidence-based sustainable behaviors, which are key aspects in preparing future generations to face environmental challenges responsibly.

Misconceptions in Climate Change Education

Climate change education is an evolving topic in both social and scientific contexts, and its role in the curriculum needs careful assessment to ensure its effectiveness in preparing informed and engaged citizens for a sustainable future. Misconceptions in science education refer to persistent ideas that contradict established scientific knowledge, affecting how students interpret new information and limiting their conceptual learning. These ideas may arise from prior experiences, deficiencies in teaching, inaccuracies in educational materials, ambiguous language in textbooks, and the oversimplification of concepts (Oberoi, 2017). Recent studies indicate that misconceptions are one of the primary barriers to acquiring scientific knowledge and that their correction requires specific teaching strategies, such as using conceptual models and cognitive conflict-based methodologies (Soeharto et al., 2019).

The understanding of environmental processes is also hindered by the persistence of these misconceptions, making it difficult for students to assimilate new scientific knowledge related to the climate system. Climate change is a conceptually complex phenomenon, as its global nature makes it challenging to observe at a local scale, and the gradual rise in temperature is not easily noticeable in daily life, which adds to the existing confusion on the topic (Farmer & Cook, 2013). However, conceptual errors about climate systems can have multiple causes, including deficiencies in teaching, inaccurate or outdated educational materials (Bozkurt, 2019) and, particularly, the resistance of certain beliefs to change even when faced with scientific evidence (Furió et al., 2006). Transforming these misconceptions remains a key challenge for environmental literacy, as they persist despite formal instruction (Hellden & Solomon, 2004).

Even though many science teachers express interest in teaching climate-related topics, gaps in their scientific training often hinder their ability to do so effectively. Many cite a lack of preparation and up-to-date knowledge as significant barriers (Monroe et al., 2013). Consequently, teachers with low environmental literacy tend to perpetuate misconceptions about climate science in their classrooms, reinforcing misinformation (Erbasan & Erkol, 2019; Plutzer et al., 2016; Summers et al., 2001). This results in learning gaps among students, leading to misinterpretations of key climate phenomena (Butler et al., 2015; Papadimitriou, 2004). Recent studies show that students often hold misconceptions about the causes of climate change, mirroring those of their teachers (Nation & Feldman, 2021). Although environmental education has been integrated into teacher training curricula, research highlights a disconnect between theoretical knowledge and its practical application in the classroom (Yusup et al., 2021).

Moreover, the primary source of learning about climate change for most students comes from the media rather than formal environmental education, which can promote the spread of misconceptions and add challenges for teachers in teaching the subject (Liu et al., 2015). In this regard, Loy et al. (2020) found a positive relationship between informational self-efficacy and knowledge of the climate system, where participants with higher informational self-efficacy reported more pro-environmental actions.

According to the above, overcoming misconceptions in climate change education is essential for strengthening scientific literacy and fostering informed understanding. Enhancing teacher training is the first step in tackling the root causes of these misconceptions and misinformation, ensuring a more accurate and effective approach to climate change education.

Beliefs About Climate and the Environmental Future in Science Education

Science teachers' beliefs about the content they teach can significantly influence how these topics are presented in the classroom (Wallace, 2014). Many secondary science teachers tend to avoid controversial topics and potential conflicts with students or the educational community (Sadler et al., 2006). However, when teaching about climate change, educators face the challenge of balancing their own beliefs with the need to convey accurate scientific information, creating spaces for reflective discussions that help students develop critical thinking (McNeal et al., 2014). Furthermore, personal interests and academic background play a crucial role in shaping teachers' motivation to incorporate climate change education into their instruction (McNeal et al., 2017). The study by Nation and Feldman (2021) shows that personal beliefs influence instruction, with those more engaged in the subject tending to teach it more effectively. However, several teachers admitted to excluding their convictions when addressing climate-related topics in the classroom, perceiving climate change as a controversial and politically sensitive issue. As a result, they avoid expressing their personal beliefs during instruction and instead adopt a “neutral” stance, aiming to let students draw their conclusions through data analysis, argumentation, and discussion. However, in practice, this neutrality rarely translates into active classroom debate, as teachers often fail to foster dialogue in either large or small groups, ultimately limiting students’ critical thinking development.

Broader beliefs about the environmental future further complicate this reluctance to engage deeply with climate issues in the classroom. Beliefs about the environmental future refer to people's perceptions, expectations, and subjective evaluations regarding the future state of the environment and the effects of climate change. These beliefs can be categorized as optimistic, pessimistic, or catastrophist (Gifford et al., 2009). Environmental optimism is based on trust in technological and political solutions to mitigate environmental problems effectively (Sagasti, 1989). Environmental pessimism, on the other hand, reflects the perception of inevitable environmental deterioration, though without a completely catastrophic outlook (McElwee & Brittain, 2009), while environmental catastrophism is characterized by the belief that environmental damage is irreversible and will lead to ecological and social collapse (Cassegård & Thörn, 2018).

Regarding the relationship between these beliefs and environmental literacy levels, studies have shown that individuals with high levels of actual literacy tend to develop more balanced and well-founded beliefs about the environmental future (Kaida & Kaida, 2016). In contrast, individuals with high self-perceived literacy but low actual knowledge may adopt extreme positions, either denying environmental problems or engaging in excessive fatalism (Páramo et al., 2015). Moreover, beliefs about the environmental future have a direct impact on the adoption of pro-environmental behaviors. According to MacKinnon et al. (2022), environmental optimism can encourage ecological actions by fostering a hopeful attitude toward change. However, excessive optimism can lead to inaction under the assumption that others will solve the problem. Meanwhile, moderate pessimism can promote sustainable behaviors by creating a sense of urgency, whereas extreme catastrophism tends to provoke hopelessness and social demobilization (Cassegård & Thörn, 2018).

Given these dynamics, there is a pressing need for pedagogical strategies that empower teachers to address climate topics effectively—without resorting to self-censorship or false equivalence—while helping students critically engage with different perspectives on the future of the environment.

Pro-Environmental Behavior

Pro-environmental behavior refers to voluntary actions aimed at minimizing negative environmental impact and promoting sustainability. These behaviors include recycling, reducing energy consumption, responsible water use, sustainable mobility, and participation in conservation initiatives, among others. However, the adoption of such behaviors is not solely dependent on personal motivation or ecological values; rather, it is closely linked to environmental literacy. Research in this field has identified three different types of pro-environmental behaviors influenced by environmental literacy (Lee et al., 2014; Zainuri et al., 2022):

- Direct behaviors: recycling, efficient resource use, reducing energy consumption.
- Indirect behaviors: supporting environmental policies, environmental education, ecological activism.
- Mitigation behaviors include using public transportation, reducing meat consumption, and purchasing eco-friendly products.

Numerous studies have demonstrated that environmental literacy influences the adoption of pro-environmental behaviors, though its impact varies depending on multiple factors. Maurer and Bogner (2020) found that environmental knowledge has a more significant effect when combined with ecological values and perceived self-efficacy, meaning the belief that individual actions can make a difference. Similarly, values and attitudes strengthen the relationship between literacy and behavior. Díaz-Siefer et al. (2015) showed that knowledge of environmental systems has an indirect effect on ecological behavior through environmental values. In other words, when people understand environmental issues and connect them to their daily lives, they are more likely to engage in pro-environmental actions. These findings highlight the importance of a comprehensive environmental education that not only provides knowledge about the environment but also fosters ecological values and a sense of self-efficacy, ultimately promoting the long-term adoption of sustainable behaviors.

The current study

The purpose is to examine the fit between the real and the self-perceived level of environmental literacy of experimental science teachers in Compulsory Secondary Education and Baccalaureate in Spanish-speaking countries. It also inquires about the impact of environmental literacy on beliefs about the future of the environment and pro-environmental behavior.

Specifically, we aim to assess the level of fit between the self-perceived level of environmental literacy and the actual level of knowledge about ESS. In this regard, the hypothesis is that there is no fit between the self-perceived level of environmental literacy and the actual level of knowledge, with a tendency to overestimate one's level of literacy (H1). We also aim to analyze the relationship between actual and perceived levels of environmental literacy and pro-environmental behavior and beliefs about the environmental future. From this objective, two hypotheses are proposed:

(H2.1) There is a positive association between both actual and self-perceived environmental literacy and optimistic beliefs about the environmental future.

(H2.2) Higher levels of actual and self-perceived environmental literacy will be positively associated with greater engagement in pro-environmental behavior.

Finally, we will analyze the relationship between beliefs about the future of the environment and pro-environmental behavior. Based on the literature review conducted, we hypothesize that optimistic environmental future beliefs are related to more pro-environmental behavior (H3).

Methodology

Participants

The sample's universe included teachers or future teachers of experimental sciences (Biology, Geology, Physics, Chemistry, Earth and Environmental Sciences) at the secondary school and baccalaureate levels in Spain and Latin America.

The final sample consisted of N=433 experimental sciences teachers or future teachers who met the eligibility criteria. 30.3% of the sample were men, 68.1% were women, and 1.6% did not answer. Regarding the country of residence, 86.1% lived in Spain, 13.2% in several countries in Latin America (Colombia, Ecuador, Mexico, Chile, Dominican Republic, Panama, Costa Rica and Bolivia), one person in Germany, one person in Denmark and one person in the United States. A total of 88% had science teaching experience.

The required sample size was calculated using the software GPower for a small effect size (d=0.2) and a statistical power of 0.95. A minimum sample of 327 participants was determined to be necessary. Therefore, the actual study sample met the minimum requirement and was more than sufficient for this research.

Instrument

For data collection, a Forms Office online questionnaire that gathered the scales designed *ad hoc* by the researchers was used; it had a total of 31 items.

The real level of environmental literacy

Nine items with a 5-point Likert-type scale assessed the real level of environmental literacy of the participant (e.g., “If we eliminate all CO_2 emissions, the planet will start cooling immediately due to the reduction of greenhouse gases in the atmosphere”). This scale had good reliability ($\boldsymbol{\alpha}$=0.80). The Exploratory Factor Analysis (EFA) performed

(Varimax rotation and Principal Components Analysis) showed a KMO index of 0.87 (>0.80), and Bartlett's test of sphericity was significant (p<0.001), so conducting the EFA was appropriate. One factor was extracted that explained 40.17% of the variance, confirming the construct validity of the scale.

Self-perceived level of environmental literacy

Six items with a 5-point Likert-type scale were used to measure the self-perceived level of environmental literacy of participants (e.g., "I am able to describe the main causes of the greenhouse effect and its relation to climate change"). The scale had excellent reliability, with a Cronbach alpha coefficient ($\boldsymbol{\alpha}$) of 0.90. An Exploratory Factor Analysis was performed using Varimax rotation and Principal Components Analysis since the KMO index was 0.87 (>0.80) and Bartlett's test of sphericity was significant (p<0.001), conducting the EFA was appropriate. The analysis showed that one factor was extracted that explained 72.75% of the variance, confirming the construct validity of the scale.

Beliefs about the environmental future

An open-ended question, "Do you think humanity will find a solution to environmental problems?" was used to establish beliefs on the environmental future. A content analysis created a categorical variable for the subsequent quantitative analysis.

First, the categories catastrophism and optimism were predefined based on the literature review conducted prior to the analysis of the data. However, when analyzing the answers, another category was added ad hoc, labeled "other," since it was needed to categorize all answers. Thus, three categories emerged:

- Catastrophism: the belief that environmental damage is irreversible and will lead to ecological and social collapse (Cassegård & Thörn, 2018).
- Optimism: the belief that technological and political solutions will be effective in mitigating environmental problems (Sagasti, 1989).
- Other: answers that do not fit in either of the categories, either because of their ambiguity or because they answered topics different from those asked.

After this, answers were categorized based on the presence of certain keywords (such as "no," "yes," "impossible," "hope," "optimist") and then coded with 0 being "catastrophism," 1 "optimism," and 2 "other." The codification was double-checked by another researcher, who independently classified the answers in the categories created. Discrepancies in the categorization of some answers were solved by consensus between both researchers, increasing the reliability of the codification. Finally, the frequency of each category was calculated (see Table 1).

Table 1.
Frequency table – Beliefs about the environmental future.

	%
Optimistic beliefs	43
Catastrophist beliefs	46.2
Other	10.9

Pro-environmental behavior

It was assessed with nine items on a 5-point Likert-type scale (e.g., “Are you willing to pay more for products that have less environmental impact?”). The scale had acceptable reliability (α=0.78). The EFA conducted (Varimax rotation and Principal Components Analysis) was appropriate since the KMO index was 0.80 and Bartlett’s test of sphericity was significant ($p<0.001$). In this case, two factors were extracted. The first one explained 27.62% of the variance, and the second was 22.84% of the variance. Table 2 shows the factor loadings. After reviewing the items, it was determined that these factors correspond to two types of pro-environmental behaviors: high-personal-cost behaviors (e.g., “Are you willing to pay more for products that have less environmental impact?”) and low-personal-cost behaviors (e.g., “Do you switch off lights and electrical appliances when not in use?”). Later analyses were conducted using the general index of the whole scale since it made theoretical sense; the general scale had a better Cronbach’s α than the subscales, and both factors were moderately strongly correlated (r=0.499).

Table 2.

Factor loadings of the Pro-environmental behavior scale (rotated matrix).

	High-personal-cost behavior	Low-personal-cost behavior
Do you make an effort to consume local products?	0.70	
Do you support or participate in wilderness conservation campaigns?	0.78	
Are you willing to pay more for products that have less environmental impact?	0.69	
Do you share information on climate change?	0.69	
Do you try to reduce the amount of water you use?		0.69
Do you practice recycling by separating waste at home?		0.71
Do you try to reduce plastic consumption in your shopping?		0.57
Do you switch off lights and electrical appliances when not in use?		0.68
Do you care about not consuming endangered animals or plants?		0.42

Demographic information

Regarding demographic information, participants were asked about their academic background, country of residence, sex, current degree being pursued (if any), experience in science teaching, the subjects taught (if applicable), and the age of their students. The personally identifiable information of the respondents was accessible only to the researcher in charge of data analysis.

Procedure

A strategic, non-probabilistic sampling method was used. The questionnaire was sent to the specific population needed, specifically to students enrolled in any of the previously detailed master's programs at a private Spanish university. Additionally, the questionnaire was sent to active teachers of any subject related to Earth System Sciences through the faculty directories of public and private secondary schools, high schools, and vocational training centers.

The first page of the questionnaire described the study's aims, assured that the data would be treated anonymously and that participation was voluntary, and asked for consent to use the data.

Data Analysis

Various statistical analysis techniques were used to analyze the data, using a confidence interval of 95% and the standard criterion $p<0.05$. All analyses were performed with IBM SPSS V28 statistical analysis software. A correlational analysis was conducted to check for any relationships between the variables' self-perceived level of environmental literacy, real environmental literacy level, and pro-environmental behavior. To check hypothesis 1, a Student's t-test for one sample was conducted. To check hypothesis 2.1, three one-way ANOVA tests were conducted. To check hypothesis 2.2, multiple linear regression analysis was used.

Results

First, Table 3 shows the percentage of correct (chose 4 or 5), neutral (chose 3), and incorrect (chose 1 or 2) answers about the level of environmental literacy, which are based on false assumptions or misconceptions about environmental issues (that is, one was “totally agree” and 5 “totally disagree”).

Table 3.
Frequency table – Real level of environmental literacy.

	% correct	% neutral	% incorrect
The seasons are caused by the varying distance between the Earth and the Sun throughout the year.	38.2	7.6	54.2
The greenhouse effect began with the Industrial Revolution	38.6	19.2	42.3
The current amount of CO_2 in the atmosphere is the highest ever recorded in the planet's history.	33.5	17.8	48.7
If the albedo of a surface increases, its temperature increases.	44.1	31.4	24.5
There is less total water on the planet than before the Industrial Revolution.	59.4	23.8	16.9
The hole in the ozone layer is one of the main causes of today's global warming.	56.3	10.4	33.3
At current concentrations. CO_2 could be toxic to the health of living organisms.	43.2	24.2	32.6
If we eliminate all CO_2 emissions. the planet would start cooling immediately due to the reduction of greenhouse gases in the atmosphere.	50.3	25.6	24
Aquifers are isolated reservoirs of fresh groundwater that are recharged by nearby rivers and lakes.	34.7	12	53.2

Table 4 shows the correlations and descriptive statistics of the variable’s Real level of environmental literacy, Self-reported level of environmental literacy and Pro-environmental behavior.

Table 4.

Correlations, means and standard deviation.

	2	3	*M*	*DT*
1. Real literacy	**0.31****	**0.10***	3.22	0.88
2. Self-perceived literacy		**0.40****	4.07	0.67
3. Pro-environmental behavior			3.92	0.60

*Note. *p < .05. **p < .001*

Regarding H1 ("There is no fit between the self-perceived level of environmental literacy and the actual level of knowledge, with a tendency to overestimate one's level of literacy"), the Student's t-test showed there were significant differences between the self-perceived level of environmental literacy and the real level of environmental literacy (t= -19.31; p<0.001; Cohen's d=0.92), with participants stating a higher level of self-perceived literacy than they actually have.

Regarding H2.1 ("There is a positive association between both actual and self-perceived environmental literacy and optimistic beliefs about the environmental future"), the results of the two one-way ANOVAs show no significant differences between groups (catastrophism, optimism and others) on the real level of environmental literacy (F=1.33; p=0.26) or the self-perceived level of environmental literacy (F=0.96; p=0.38). Table 5 presents the descriptive statistics for each group across the variables.

Table 5.

Descriptive statistics of each group in the real level of literacy and self-perceived level of literacy.

		N	*M*	*DT*
Real literacy	Catastrophism	199	3.27	0.93
	Optimism	184	3.14	0.84
	Other	47	3.30	0.84
Self-perceived literacy	Catastrophism	200	4.12	0.64
	Optimism	186	4.04	0.67
	Other	47	4.02	0.77

Results of the multiple linear regression analyses performed to check H2.2 ("Higher levels of actual and self-perceived environmental literacy will be positively associated with greater engagement in pro-environmental behavior") showed that the self-perceived level of environmental literacy (β=0.41; p<0.001; [0.21; 0.45]) is a significant predictor of pro-environmental behavior (R^2 adjusted=0.16; p<0.001), whilst the real level of environmental literacy isn't (β=0.02; p=0.58).

Finally, regarding H3 ("Optimistic environmental future beliefs are related to more pro-environmental behavior"), as Levene's statistic was significant (p<0.05), the homoscedasticity assumption was not met, so we conducted non-parametric analysis, specifically Kruskal-Wallis test, that showed there were no significant differences between groups (catastrophism, optimism and other) in pro-environmental behavior (Kruskal-Wallis H=0.36; p=0.833). Table 6 shows the average range of each group.

Table 6.

The average range of each group in pro-environmental behavior.

	N	Average range

Pro-environmental behavior	Catastrophism	200	214.15
	Optimism	186	217.74
	Other	47	226.19

Discussion

Limited Knowledge About the Climate System

The first result highlights a low level of environmental literacy among science teachers, evidenced by a high percentage of incorrect answers. This lack of knowledge about the climate system among current and future educators has also been reported in previous studies, such as those by Díaz-Siefer et al. (2015) and Goulgouti et al. (2019). The present study reaffirms the prevalence of misconceptions (see Table 3) that have been identified by other authors (Nation & Feldman, 2021), including the belief that the greenhouse effect began with the Industrial Revolution (42.3%) or that the depletion of the ozone layer is one of the main causes of current global warming (33.3%).

Another widely held misconception about the climate system is the idea that the seasons result from variations in the distance between the Earth and the Sun throughout the year (54.2%). Additionally, a high level of uncertainty is evident, as reflected in the significant proportion of neutral responses ("neither agree nor disagree") regarding the impact of surface albedo on temperature (31.4%). Finally, a considerable number of participants mistakenly believe that current CO_2 concentrations are the highest ever recorded in the history of the planet (48.7%) (see Table 3).

The Illusion of Knowledge

The findings of the present study corroborate previous research, indicating a significant discrepancy between self-perceived and actual environmental literacy levels. The results revealed that participants tended to overestimate their environmental knowledge, aligning with the studies by Mundt et al. (2024) or Rosdiana et al. (2020), which demonstrated that confidence in environmental knowledge does not always translate into higher literacy. Similarly, Sarıbaş et al. (2014) highlighted this overestimation as a potential barrier to informed decision-making and sustainable behavior, increasing the risk of misinformation, as also mentioned by Bert et al. (2023). These findings highlight the need for educational strategies that not only promote knowledge acquisition but also enhance self-awareness among science teachers, helping them recognize the limits of their understanding.

Fostering critical thinking and accurate self-assessment in environmental education is essential for bridging the gap between perceived and actual literacy. Teacher training programs should incorporate strategies that equip educators to address scientific uncertainty and the controversial aspects of climate change in the classroom. To achieve this, these programs must focus on correcting misconceptions through active methodologies and an interdisciplinary approach, thereby enhancing both environmental literacy and confidence in teaching climate system topics (Dada et al., 2017; Önder & Kocaeren, 2015; Sahin et al., 2020).

Additionally, integrating computational and systems thinking within a progressive model could significantly improve climate change comprehension and facilitate its teaching (Breslyn & McGinnis, 2019). Moreover, educational experiences in semi-authentic environments have shown promising results in fostering a deeper understanding of environmental issues (Bissinger & Bogner, 2018).

The Role of Beliefs in Environmental Perspectives

Even though several studies show that literacy levels play a crucial role in shaping beliefs about the environmental future—where higher literacy levels foster balanced perspectives, while overestimated self-perceived literacy levels lead to catastrophism (Kaida & Kaida, 2016; Páramo et al., 2015)—the current study did not find significant differences in actual and self-perceived environmental literacy levels between teachers with catastrophist and optimist beliefs. Additionally, previous research has found that beliefs about the environmental future directly influence pro-environmental behaviors, although the evidence on this matter remains contradictory (Cassegård & Thörn, 2018; MacKinnon et al., 2022). However, in this study, no relationship was found between beliefs about the environmental future and pro-environmental behavior. Although this contradicts some previous research, it suggests that the link between beliefs and behavior may be more complex and mediated by other factors, leaving the issue open for further research.

Relationship Between Environmental Literacy and Pro-Environmental Behavior

This analysis was based on the hypothesis that higher levels of both actual and self-perceived environmental literacy would lead to more pro-environmental behavior. The results indicate that while self-perceived environmental literacy is a significant predictor of pro-environmental behavior, actual environmental literacy is not. Therefore, it is not real knowledge that leads to more pro-environmental behavior but the self-perception of the knowledge one believes to have. This research also found that teachers tend to think they know more than they actually know, and misconceptions might guide their behaviors. The finding contradicts the study by Dopelt et al. (2020), who found that university students with higher levels of environmental knowledge demonstrated more pro-environmental attitudes and behaviors. Similarly, Díaz-Siefer et al. (2015) reported that knowledge of the human-environment system in the Chilean adult population positively correlated with pro-environmental behavior.

A key debate in environmental education is whether scientific knowledge alone is sufficient to drive behavioral change. Maurer and Bogner (2020) found interesting results in upper primary school students, concluding that environmental knowledge alone is not sufficient to promote pro-environmental behavior. Instead, environmental values play a fundamental role as mediators between literacy levels and behavior. Pongiglione (2011) argues that increasing scientific knowledge about climate change does not necessarily induce significant shifts in behavior, as psychological mechanisms can lead to apathy and inaction even when individuals recognize the associated risks. This perspective highlights the limitations of an information-based approach to environmental literacy, suggesting that knowledge alone does not guarantee pro-environmental engagement.

The findings of this study align with the broader view that environmental literacy must extend beyond mere awareness and pro-environmental behaviors; it requires a holistic approach that integrates scientific knowledge, values, and action. While environmental values play a crucial role in promoting sustainability, they must be supported by a strong foundation in scientific knowledge to ensure that well-intentioned actions are effective rather than misguided. Knowledge remains an essential enabler for informed decision-making and meaningful engagement, but it must be accompanied by strategies that mitigate psychological barriers to action.

Thus, rather than viewing knowledge as the sole driver of behavioral change, this study supports the idea that a comprehensive environmental education framework should incorporate a systemic perspective, interdisciplinary approaches, active learning methodologies, and real-world engagement. By fostering an educational environment where scientific literacy is integrated with critical thinking, emotional engagement, and practical action, it becomes possible to bridge the gap between knowledge and behavior, addressing limitations highlighted by Pongiglione (2011).

Limitations

The results of this study should be interpreted with caution, as certain methodological limitations must be acknowledged.

First, although reliability and construct validity tests were conducted for the instruments used, they were specifically designed for this study rather than adapted from pre-existing, validated scales tested across diverse samples. Additionally, the sample comprises participants of different nationalities, which presents another limitation, as potential cultural differences were not accounted for. Future research could address these differences to enhance generalizability.

Moreover, the content analysis conducted may lead to a reductionist interpretation of the data, as the semantic richness of responses could be lost. Besides, the fact that only two researchers performed codification diminishes its reliability. Furthermore, the absence of significant differences between groups in pro-environmental behavior and real and self-perceived levels of environmental literacy might be influenced by this categorization, which largely depends on the researchers' interpretations. Even when using previously established categories, the process of assigning meanings to terms and phrases may be subject to personal biases, introducing a margin of error in data classification and analysis.

Conclusions

Environmental literacy is a cornerstone of sustainability education and science teaching. However, the persistent gap between teachers' self-perception and actual knowledge underscores the urgent need for specialized training grounded in Earth System Science (ESS). Strengthening environmental literacy among educators is essential to raising awareness of knowledge limitations and equipping them with tools to guide future generations in understanding and mitigating climate change.

This study highlights that misconceptions about the climate system remain prevalent among science teachers, reinforcing the need for strategies that promote knowledge acquisition and enhance self-awareness. Fostering critical thinking and accurate self-assessment is vital to bridging the gap between perceived and actual literacy. Accordingly, teacher training programs must include components that prepare educators to address scientific uncertainty and the controversial nature of climate change. These programs should focus on correcting misconceptions through active methodologies and interdisciplinary approaches, thereby enhancing both literacy and confidence in teaching climate-related topics.

A key finding is that self-perceived environmental literacy, rather than actual knowledge, is a stronger predictor of pro-environmental behavior. This suggests that behaviors are often driven more by what individuals believe they know than by their real understanding. This has important implications, as overestimating one's knowledge may lead to misguided actions or resistance to new information. Psychological theories such as the Dunning-Kruger effect help explain how limited knowledge can foster overconfidence, reducing openness to learning or adopting better-informed behaviors. While previous studies have found positive correlations between knowledge and pro-environmental behavior, our findings align with broader perspectives, suggesting that knowledge alone is insufficient to drive change. Although environmental values were not directly assessed in this study, previous research suggests they may mediate the relationship between literacy and behavior. Therefore, our interpretation aligns with existing theoretical frameworks on value-driven engagement.

Moreover, the findings suggest that teachers' beliefs about the environmental future do not necessarily correlate with actual knowledge. Although previous research has linked literacy levels to more balanced environmental perspectives—where overestimated perceived knowledge can lead to catastrophism—this study did not find significant differences in real or perceived literacy between teachers with catastrophist and optimist beliefs. Likewise, although earlier studies suggest that such beliefs influence behavior, our results show no direct relationship, leaving this issue open for further investigation.

To address these challenges, environmental education must move beyond a purely information-based model and integrate emotional, psychological, and behavioral dimensions. A systems approach through ESS is essential for fostering a comprehensive understanding of planetary dynamics. Integrating ESS into teacher training and curricula is thus crucial for improving climate literacy and preparing students to address global change. These sciences offer the necessary framework to understand complex interactions among Earth's subsystems, including matter and energy flows that regulate climate and environmental stability. ESS provides a systemic lens through which to explore Earth's dynamics. It enables learners to recognize relationships among environmental components and understand climate change at multiple scales. Education grounded in ESS enhances students' capacity for systems thinking and promotes scientifically grounded responses to environmental challenges. Embracing this perspective allows learners to adopt a multidisciplinary approach to problem-solving and develop robust scientific reasoning skills. Despite significant progress in ESS education in the United States, its incorporation into curricula in Spanish-speaking countries remains limited. Environmental issues are often presented in a fragmented and descriptive manner rather than through frameworks that integrate ecological, social, and economic dimensions. This lack of a holistic vision hinders students' ability to perceive Earth as an interconnected system and weakens their capacity for critical thinking and informed sustainability decision-making.

Without a solid scientific foundation, individuals are more likely to rely solely on personal beliefs or values, increasing their vulnerability to political and economic manipulation. This makes them more susceptible to strategies serving particular interests rather than promoting collective sustainability. Consequently, integrating ESS into the training of all science teachers responsible for climate-related content is essential. Only with a rigorous, evidence-based understanding of Earth's processes will educators be equipped to foster critical thinking and informed decision-making in their students. A strong grounding in ESS ensures that climate education moves beyond value transmission, empowering citizens to analyze, question, and act responsibly in the face of 21st-century environmental challenges.

To translate these findings into practice, teacher training programs should incorporate components that develop metacognitive awareness, enabling educators to assess their environmental knowledge and recognize misconceptions. Reflective tools, formative assessments, and structured feedback can help reduce overconfidence and support continuous professional growth. Embedding ESS within interdisciplinary modules and active learning strategies—such as inquiry-based learning, role-play on controversial issues, or systems thinking tasks—can strengthen both conceptual understanding and teaching efficacy in complex environmental topics. These elements are essential to prepare teachers who are scientifically literate and pedagogically equipped to foster meaningful environmental engagement.

Finally, curriculum design and teacher training initiatives should include targeted interventions to address the misconceptions identified in this study, particularly those concerning the climate system. Diagnostic assessments at the beginning of training modules can help identify prior misunderstandings and overestimation of knowledge. These should be followed by metacognitive strategies—such as confidence rating exercises, self-explanation prompts, and structured reflection activities—aimed at promoting conceptual change. Curricula should treat ESS as a transversal axis rather than a compartmentalized topic, fostering systemic and interdisciplinary thinking. Active learning strategies—such as case-based learning, model-based reasoning, and simulations—can help educators internalize complex climate concepts and develop pedagogical tools to instill systems thinking in their students. In doing so, training programs will not only improve content mastery but also empower educators to navigate uncertainty and emotionally charged environmental issues with greater confidence and competence.

Declarations

Author Contributions

Conceptualization: Garrido, G. **Data curation:** Garrido, G.; Morcillo, F.; Arana-Cuenca, A. **Methodology, software, validation, and formal analysis:** Arribas-Tiemblo, I.M.; Arana-Cuenca, A. **Investigation and writing-original draft**: Garrido, G.; Arribas-Tiemblo, I.M.; Morcillo, F.; Arana-Cuenca, A. **Writing—review and editing**: Garrido, G.; Arribas-Tiemblo, I.M.; Morcillo, F.; Arana-Cuenca, A. All authors have read and agreed to the published version of the manuscript.

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Statements and Claims

Ethical Considerations: The Research Ethics Committee of UNIR has granted ethical approval for this study under approval code PI: 134/2024 following the review of the submitted documentation.

Consent to Participate: The first page of the questionnaire outlined the aims of the study, assured participants that their data would be treated anonymously, and clarified that participation was voluntary. By proceeding with the questionnaire, participants provided their informed consent for the use of their data in this research.

Consent for Publication: This study does not include identifiable personal data, images, or videos of individual participants. Therefore, informed consent for publication is not applicable.

Conflict of Interest Statement: The authors declare that they have no conflicts of interest related to this study.

Funding Statement: This research received no external funding.

Data Availability Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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