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ARTICLE

Climate Change: A Pre-Service Teachers' Intervention Program

Anat Abramovich[1] and Sophie Shauli[2]

[1]Tel-Aviv University and Gordon College of Education, Tel Aviv, Israel and [2]Gordon College of Education, Haifa, Israel
Corresponding author: Anat Abramovich; Email: anatab@gordon.ac.il

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Abstract

This study examined the impact of a short-term climate literacy (CL) course on pre-service teachers (PSTs) at a local college in Israel. Thirty-six science and communication PSTs participated. Using a mixed methods approach, pre and post-course questionnaires and assignment responses showed significant improvements in climate change knowledge and environmentally responsible behaviour (ERB) after the course. PSTs' attitudes were key predictors of their ERB. The qualitative analysis supported these findings, revealing that the participants who were able to express complex climate knowledge also intended to reflect more environmentally responsible behaviour. 52.2% of participants with complex climate knowledge used diverse knowledge types to express ideas, reflecting a real commitment to environmental attitudes and personal behaviour. While 65% raised climate awareness within their families, only 33% discussed it, during their practicum, with students. Overall, the course significantly enhanced PSTs' climate literacy in knowledge, attitudes and behaviour, even as a limited workshop. According to the findings, courses that promote climate literacy are necessary. The findings of this study indicate that a well-established short-term intervention may affect participants regarding a significant issue like climate change.

Keywords: Climate change; climate literacy; environmental behaviour; online course intervention; pre-service teachers

Introduction

Climate change (CC) is one of the most urgent issues facing governments and individuals alike. Though significant progress has been made regarding policy commitments, ambitions and implementation remain far below the level necessary to reduce greenhouse gas emissions (mitigation) and limit global warming to 1.5 and 2 degrees Celsius. The importance of education as a mitigation strategy has been highlighted by several researchers (DeWaters *et al.*, 2014; Kolenatý *et al.*, 2022; Kumar *et al.*, 2023; Li, Monroe, Oxarart & Ritchie 2019; Monroe, Riley & White 2024; NAAEE, 2024). In Israel, the Ministry of Education decided that in 2022, all students will learn about climate change in elementary, middle and high schools for 30 hours a year (Israeli Ministry of Education, 2022). According to this decision, the learning will be embedded through different topics such as science, literature, communication, history, etc. Pre-service teachers (PSTs), as the educators of tomorrow, should be prepared to lead social change. Being aware of time limitation concerning PSTs education, we designed a short and focused intervention in an Israeli academic educational college. A module, consisting of five asynchronous lessons and two synchronous face-to-face lessons, integrating educational technology was incorporated into a workshop environment. We designed the lessons to increase PSTs' environmental climate knowledge and attitudes and motivate them to adopt mitigation strategies. We aimed at the development of scientific literacy that could be a valuable tool for enhancing students' scientific understanding and linking science to everyday life and society (Ke *et al.*, 2022; Shauli & Baram-Tsabari, 2019). Likewise, at promoting climate literacy (CL) that might contribute to the development of knowledge and personal behaviour related to CC (Hornsey & Lewandowsky, 2022; Simpson *et al.*, 2021). To verify the efficiency of this module, we raised the following questions:

(1) What are the effects of a short-term intervention in teacher training on climate literacy, specifically on knowledge, attitudes and behaviour?

(2) How do the components of the climate literacy questionnaire relate to each other, and what are the characteristics of this relationship?

This study proposes a new perspective on CC programmes as well as a novel method for measuring CL and examines the relationship between its various components.

Literature review

The critical global issue of climate change is confirmed by the Intergovernmental Panel on Climate Change's (IPCC) sixth report (2021) to be driven by human-caused greenhouse gas emissions, posing a significant challenge for governments and individuals worldwide. Although progress has been made in policy commitments, efforts to limit global warming to 1.5–2 °C remain inadequate. Public support for climate policies is crucial to achieving these goals (Dabla-Norris *et al.*, 2023), and CL is vital for fostering this understanding and promoting behavioural change.

Climate literacy

There are several definitions for CL. The US Global Change Research Program (USGCRP, 2009) describes CL as the understanding of one's influence on climate and vice versa. "A climate-literate person understands the essential principles of Earth's climate system; knows how to assess scientifically credible climate information; communicates about climate and climate change in a meaningful way; is able to make informed and responsible decisions with regard to actions that may affect climate" (USGCRP, p. 4). Meaning CL is composed of scientific climate knowledge, attitudes, skills to discuss the issue properly, and responsible environmental actions. Several researchers relied on this definition in their studies (e.g. Azevedo & Marques, 2017; Leve *et al.*, 2023; Milér & Sládek, 2011; Mittenzwei *et al.*, 2019) Others adopted some of the components. Bedford (2016) and Dzambo et al. (2020) focused on the knowledge part of CL definition (USGCRP, 2009). Dupigny-Giroux (2008) measured knowledge, skills and behaviours related to climate change and its impacts for CL. Dupigny-Giroux (2008) included the understanding of the interconnectedness and complexity of climate patterns, human influence and the ability to act accordingly. DeWaters *et al.*, (2014) definition includes: knowledge (cognition), attitudes (affection) and behaviour as the components of CL. As well, DeWaters *et al.*, (2014), as did we, were aiming to develop higher-order thinking skills associated with handling real-world data through an instructional module and an assessment instrument. CL's goal is to achieve environmentally responsible behaviour (ERB). While the USGCRP (2009) defines CL as the understanding of reciprocal influence on climate and the ability to engage with climate information and decision-making, DeWaters *et al.*, (2014) expands this definition for higher education by explicitly incorporating cognitive, affective and behavioural components, with the ultimate goal of achieving environmentally responsible behaviour (ERB).We find DeWaters *et al.*, (2014) definition as best meeting the CL components acquired and evaluated in higher education.

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Environmental responsible behaviour (ERB)

Environmental responsible behaviour (ERB) requires an in-depth understanding of nature's complexity as well as human needs and capabilities (Abramovich & Loria, 2015; Stern, 2000; Tal & Abramovich, 2013; Ünal *et al.*, 2019). However, it is difficult to predict participants' ERBs or identify characteristics or conditions that might influence their behaviour. Further, no conclusive answer exists regarding which variables influence ERB. Knowledge, for example, is often considered to be the first step toward ERB (Maartensson & Loi, 2022; Mikusiński *et al.*, 2023; Pitaloka & Aeni, 2024; Spiteri, 2022). However, knowledge alone does not naturally lead to ERB, as Ajzen, Joyce, Sheikh, and Cote (2011) showed. However, they did not measure the wealth of knowledge people had, but rather examined the degree of information accuracy. Nevertheless, it is widely agreed that one must develop a concern for the environment, a sense of responsibility, as well as a deep understanding of the system and its complexity (Gould, Ardoin, Thomsen & Wyman Roth 2018; Kollmuss & Agyeman, 2002; Maartensson & Loi, 2022; Pitaloka & Aeni, 2024; Stern, 2000). The studies of Gunamantha and Dantes (2019) and Wu and Otsuka (2021) showed that despite moderate knowledge of climate change, attitudes and behaviour were not significantly affected by this knowledge. Ahmad *et al.*, (2020) concluded the same in their study in Jordan, where they demonstrated statistically significant impacts for knowledge and attitude adoption, but not for practice adoption. Geiger, Geiger, and Wilhelm (2019) showed that certain domain of general knowledge (e.g., basic ecology, climate, resources, environmental contamination, economics, consumption behaviour) accounted for a small fragment (7%) of the variance in environmentally significant behaviour. Frick, Kaiser, and Wilson (2004), and Barbosa, Randler, and Robaina (2021) argue that environmental knowledge has three dimensions: system-related knowledge, action-related knowledge, and effectiveness knowledge. The first consists of ecosystem processes and human-nature interaction. The second addresses possible EBs, and the third is the least common type of knowledge. Some researchers believe that a behaviour based on comprehensive climate knowledge and literate decisions might help to reduce the exacerbation of global warming (Lehnert, Fiedor, Frajer, Hercik & Jurek 2019; Li & Monroe, 2018; Monroe *et al.*, 2024; Varela-Candamio, Novo-Corti & García-Álvarez 2018; NAAEE, 2024). Environmental education (EE) is a powerful tool for generating CL, which eventually will lead to environmentally responsible behaviour (ERB) (Azevedo & Marques, 2017; Varela-Candamio *et al.*, 2018).

Environmental education (EE) and climate change (CC)

Education is widely recognised as a powerful mitigation strategy (DeWaters *et al.*, 2014; Kolenatý *et al.*, 2022; Kumar *et al.*, 2023; Monroe *et al.*, 2024; NAAEE, 2024). School students might be the direct path to the whole family's positive behaviour change (Li & Monroe, 2018). Teaching about CC is quite complicated since educators feel uncertain/unqualified confronting climate change issues (Eilam, 2022; Li *et al.*, 2019; Monroe *et al.*, 2024). On the other hand, children are concerned about climate change, which hurts their emotional and cognitive development (Gibbs *et al.*, 2019). The North American Association for Environmental Education (NAAEE) suggests guidelines for climate educators so they could enhance knowledge, attitudes and real commitment concerning CC. They mention five key characteristics: (1) Collaborative, Welcoming, and Responsive Learning Environments; (2) Knowledge and Skills to Foster Climate Action; (3) Attention and climate emotion; (4) Locally Focused and Community Driven; (5) Civic Engagement for Climate Action. These characteristics contain cognitive and emotional components as well as the engagement of learners. Monroe and colleagues (2024) claim that a reform in education is required addressing CC, so teachers could be able to support their students. They present teaching practices (e.g. problem-based inquiry, scientists discuss their research concerning CC) and strategies (Using technology to understand climate models, deal with issues from local environment, creating environmental actions opportunities) with a strong technology focus

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(e.g. digital animation, videos) for PSTs and in-service professional development. Other researchers suggested other practices to address CC and mitigation behaviour: autonomous learning, active learning, integrating social science principles within climate literacy programmes (Bissinger & Bogner, 2018; Foss & Ko, 2019).

However, the literature points to a shortage of adequate educational materials and effective teaching strategies (Monroe *et al.*, 2017). For example, the study by Baker *et al.*, (2021) examined the perceptions of Australian parents and teachers on how children's emotions are affected by CC and adults' needs and challenges in supporting children. They found that parents and teachers similarly reported that children are very interested in CC. They pointed to a lack of resources to help teachers and parents support their children's environmental learning in a way that fosters emotional well-being and promotes hopefulness. Lawson *et al.*, (2019) examined the increasing polarisation of public opinion on climate change in the U.S. and highlighted how education can mitigate scepticism, particularly among adolescents, by enhancing their understanding of climate risks. Moreover, Eilam (2022) claims that educators' poor conceptualisation of CC is the main cause of the limited use and development of CC teaching units. Lehnert *et al.*, (2019) and several other studies (e.g. Abdullah *et al.*, 2019) confirm that knowledge and attitudes are essential for effective teaching interventions. According to the existing literature, and recognising the time limitations related to PSTs' education, we designed a short-term intervention to measure CL among PSTs, focusing on their knowledge, attitudes and personal behaviour.

It proposes an intervention to measure CL among PSTs and addresses the following research questions:

1. What are the effects of a short-term intervention in teacher training on climate literacy, specifically on knowledge, attitudes and behaviour?
2. How do the constructs of climate literacy, i.e., knowledge, attitude and environmentally responsible behaviour, relate to each other and what are the characteristics of this relationship?

Methodology

To answer these questions, a short-term CL course for PSTs was developed, designed to encourage high-level thinking and utilise educational technologies. Based on autonomous active learning principles, the course aims to empower PSTs to make knowledgeable decisions based on realistic climate information.

Research design

The objective of the course was to introduce future teachers to knowledge, attitudes and behaviours related to climate change on a personal and social level. The PSTs are the educators of tomorrow, and they should serve as ambassadors of change for their students and communities. The course consisted of seven lessons, which were integrated into teaching workshops for students in the Department of Science and the Department of Communication. Five additional lessons were conducted asynchronously as recorded video lessons and two lessons were conducted synchronously in a face-to-face format. Students participated in the course by watching the videos and answering questions that appeared in the reading materials that were accompanying the course content. A preliminary questionnaire was administered before the students were exposed to the course content, and a closing questionnaire was administered at the end of the course. The course was incorporated into two workshops (science and communication) as an optional

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Table 1. Five-session online course

Lesson	*Topic*	*Task*
lesson 1	Introduction	Impressions
In between	Smart consumption	Impressions & opinions
lesson 2	Causes & solutions	Personal opinion of what can be done
lesson 3	Experiments & activities	Report initiation of class activities
lesson 4	Food waste	Impressions & actions
lesson 5	Resources & summation	Forum summation

learning module. Participants received a bonus score from the workshop instructors. The study was conducted in three phases:

1. Participants in a face-to-face meeting completed an online pre-questionnaire.
2. Participants participated in a seven-session course that included a variety of learning activities. Two lessons were taught face-to-face, and five more were based on videos produced by the researchers. Scientific explanations, climatic concepts, photographs, videos from around the world, and experiments were incorporated into the lessons by professional video producers in the college (Table 1). Throughout each lesson, the learners were introduced to further reading, questions that required written responses, and their own experiences as teachers in the classroom. The course focused on developing 21st-century skills through technological, laboratory and scientific challenges.
3. Participants in a face-to-face meeting completed a post-questionnaire, identical to the pre-questionnaire but with two additional open-ended questions. These questions asked participants to describe changes in their ERB during the course and any actions they encouraged in their family, friends or students.

The five lessons are described in table 1.

We drew on the work of Fischer *et al.*, (2022) and González-Pérez and Ramírez-Montoya (2022), concentrating on designing learning environments and strategies, fostering systems change and assessing learning outcomes. Through the lessons, we introduced the three dimensions of environmental knowledge: Lesson 1 primarily addresses system-related knowledge (e.g., climate change and human influence), Lesson 2 emphasises action-related knowledge (ideas on what can be done about climate change) and Lesson 5 focuses on effectiveness knowledge (Barbosa *et al.*, 2021; Frick *et al.*, 2004).

Sample and data collection

Participants were all undergraduate students at the Teacher Training College. The college offers a variety of specialisations in teaching, such as mathematics, English, sciences, communication and others. Each student selects one of these subjects. Additionally, all students attend a practicum, in which PSTs attend schools once a week plus five consecutive days per semester. In this study, thirty-six PSTs were recruited from two different specialisations, 24 from the science department and 12 from the communications department.

Research tool

A 20-minute online four-part questionnaire was administered and completed by the participants during face-to-face meetings, before and after starting the unit. The questionnaire consisted of:

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1. **Climate Change Knowledge:** 16 statements (correct/incorrect), for example, "Climate change will only affect underprivileged populations and groups in more sensitive populations such as the elderly and chronically ill." In addition, an open-ended question asking participants to define climate change (pre and post)
2. **Attitude to Climate Change Issues:** 7 statements (rising type scale), e.g., "Indicate how much it concerns you that there is an increase in the use of disposable dishes." (pre and post)
3. **Daily ERB:** 17 statements describing daily personal behaviour that can influence global warming (rising type scale), e.g., "Indicate the frequency with which you shop while using reusable baskets." (pre and post)
4. **Conceptual ERB:** An open-ended question on changes in participants' ERB and action they encouraged. (post questionnaire).

In addition, we collected open-ended responses from three assignments: *Causes & Solutions* (21 responses), *Smart Consumption* (29 responses) and *Food Waste* (16 responses). These assignments encouraged participants to express their knowledge and reflect on their behaviour. For example: "The lecturer, Stewart Tristram, discusses how the public has the power to stop the waste of resources or the loss of food. Write at least two ways this can be achieved." (Lesson 5, *Food Waste*). Another example: "Share your opinion on the method of planting trees as a way to reduce carbon dioxide levels. Address environmental, economic, and social aspects." (Lesson 2, *Causes & Solutions*).

The questionnaire underwent content validity and cognitive validity tests (Karabenick *et al.*, 2007). A cognitive validation was conducted by three experts in environmental literacy education and two students who are not part of the research group. The questionnaire was revised based on these validation results. The reliability of the sub-questionnaires before and after the intervention was acceptable (Cronbach's alpha between 0.6 and 0.8).

Ethical considerations

The ethics committee of the institution approved the study in 2021. All participants were provided with detailed information outlining the commitment required.

Data analysis

This study's results underwent qualitative and quantitative analysis, in parallel. Participants' responses to the questionnaires and their comments during the course were collected. Data from the two open-ended questions in the pre- and post-questionnaire, responses and comments made during the course were analysed qualitatively using content analysis. Analysing the close-ended questions provided quantitative evidence to support the primarily qualitative findings.

Quantitative analysis

The data from the close-end parts of the questionnaire were analysed for normality, homogeneity of variances, normality of residuals, homoscedasticity, independence of observations and multicollinearity. The results of those tests met the criteria for using T-test and regression analysis. For each participant, a grade was calculated for each of the first three parts of the questionnaire: climate change knowledge, attitudes to climate change issues and daily ERB.

- **Scientific climate Change Knowledge (CK):** The percentage of correct answers was calculated (X/16*100). A low level of CK was defined as 0 to 10 correct answers (up to 62%), a medium level of CK 11 to 13 correct answers (up to 81%), and a high level of CK: 14 to 16 (82% and above).

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- **Attitudes to Climate Change Issues:** An average grade was calculated based on the degree of agreement with statements expressing concern about CC (X/28*100).
- **Daily ERB:** An average score was calculated based on the degree of agreement with expressions of mitigation behaviour (X/85*100).

Qualitative analysis

The authors utilised a double coding procedure with two independent coders, to validate the content analysis of written responses collected from students during the study. Authors developed a codebook outlining clear categories of content with examples representative of each category. Cohen's Kappa was calculated after coding 20% of the responses. There was a reliability value of 0.90.

Scientific climate change knowledge (CK)

Scientific climate change knowledge (CK) was analysed based on an open-ended question from pre-post questionnaires. We asked: "Explain in your own words and in detail what global warming or climate change is."

Scientific CK was characterised into three levels:

- **Basic Level scientific CK:** e.g., "Global warming is the rising of the earth's temperature."
- **Medium-Level scientific CK:** e.g., "Global warming causes long-range climate change. An extreme change in the temperature disrupts the natural balance and creates natural disasters."
- **Complex-Level scientific CK:** e.g., "Global warming is a phenomenon in which the average temperature of the earth is rising due to greenhouse gas emissions. Global warming has a harmful influence on the earth: storms, heavy rains, rising sea level, and flooding islands, and so forth . . . ."

Different domains of climate knowledge (CK)

Looking further at the open-ended questions from the post questionnaire and questions from the various tasks, we identified different domains of CK: ecological knowledge, knowledge about natural resources, consumption behaviour knowledge, environmental contamination knowledge and social-economic knowledge (Table 2). We noted the presence of the different domains of knowledge for each participant without counting the number of times they were used.

We conducted a further analysis of the average number of different domains of CK for each scientific CK level (post-results).

Attitudes

Attitudes were measured using statements derived from participants' answers to the open-ended questions and their responses to various assignments indicating environmental awareness. The statements were classified into environmental awareness categories according to previous research (Tal & Abramovich, 2013):

1. No concern or negative attitudes expressed
2. General care for the environment expressed
3. Concern supported by evidence for understanding and commitment expressed

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Table 2. Various domains of climate knowledge and examples

Kind of knowledge	*Example*
Ecological	Global warming can cause the extinction of species, especially currently endangered species (Gi., post questionnaire)
Natural resources	"... We reach the limit of our resources, deforestation for growing more food, using water from depleted reservoirs ... " (Wi., food loss)
Consumption	"... I often wonder about the price of a shirt I buy, knowing it is outrageous and telling myself it is better to buy second-hand clothing for the benefit of our planet ... " (As., the clothing industry)
Environmental contamination	" Food production is accompanied by deforestation, harming habitats, and massive exploitation, which will turn against us ... " (Ko., food loss).
Social-economic	"... There is no fair distribution of the earth's resources, the industrialists prefer to throw food away rather than reduce the price of the products. Consequently, not everyone can consume nutritious food" (Ro., food loss)

Following this categorisation, each participant was assigned the maximum score possible based on their awareness statements. To ensure reliability, each researcher independently coded the categories, and contradictory answers were discussed and resolved. The initial agreement was 90%. The researchers continued discussing the statements until they reached full agreement.

Environmental responsible behaviour (ERB)

Daily Environmental Responsible behaviour (ERB) was examined based on participants' responses in the post-questionnaire regarding actions they adopted after the course. Additionally, ERB levels were analysed based on expressions throughout the course tasks where participants were asked to suggest actions. For example, one question was: "Write suggestions on how to deal with climate change in the private sphere (home) and in the public sphere (neighborhood, community, school)." The analysis was based on previous studies (Abramovich & Loria, 2015; Tal & Abramovich, 2013), revealing three main categories of responses:

1. Habit-dependent or Unexplained behaviour:
2. Broadly explained behaviour based on "general care" for the environment:
3. Specifically explained and motivated by arguments about the complexity of environmental problems and explicit willingness to act to protect the environment.

To ensure reliability, each researcher independently coded the categories, answers were then compared and contradictory answers discussed. The final agreement was 90%. The researchers continued discussing the statements until they reached full agreement.

Results

This section presents PSTs' CL components: knowledge, attitudes and behaviours, according to the quantitative and qualitative analyses, followed by the interactions between those variables.

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Table 3. The average percentage of the various levels of change knowledge (CK) among participants ($N = 24$)

	Low level of CK (%)	*Medium level of CK (%)*	*High level of CK (%)*
No. of correct answers	0–10	11–13	14–16
Pre	29.2	58.3	12.5
Post	12.5	41.7	45.8

Scientific climate change knowledge (CK)

Quantitative analysis

As mentioned in the data analysis section, environmental knowledge was examined by quantitative and qualitative methods. The 16 close-ended knowledge statements were statistically analysed and as self-expressed knowledge from PSTs' answers to open-ended various assignments were contant-analysed.

Comparing the means of climate knowledge (CK) scores on the pre- and post-questionnaires using the T-test for paired samples revealed a significant increase in CK after the intervention course (pre-test: 71.1 ± 10.6; post-test: 80.99 ± 13.4). This difference was found significant with $p = 0.006$ with a medium effect size.

PSTs were further classified according to their CK levels (see paragraph 3.5.1). Table 3 presents the average percentage of each level.

Table 3 illustrates that there was a significant improvement, as only 12.5% of PSTs had low CK levels after the intervention, while about 46% had high CK levels.

Approximately 42% of participants maintained the same level before and after the intervention, while 17% increased from a low to a high level. As for the 16 knowledge statements, about 30% of the statements were high both in the pre and post questionnaires. About half of the statements showed an improvement from low/medium to medium/high. For example, the statement "The "greenhouse effect" is a phenomenon that allows life to exist on Earth" show a shift from very low (38%) to medium (75%), and the statement " Actions in the private sphere (such as replacing all old light bulbs with fluorescent bulbs) will help reduce the amount of greenhouse gases in the atmosphere" raised from low (58.3) to high (83.3) (See Appendix A). The essence of those statements was mentioned during the meetings and the assignments. The analysis indicates that the intervention aroused the participants' awareness of the main cause of climate change and the possible effect of individual actions on the phenomenon. They also understood the significant difference between the "greenhouse effect" and "climate change."

Qualitative analysis: self-expressed knowledge

Since global warming was the core focus of the intervention programme, we examined participants' scientific climate knowledge (CK) through their answer to a question in the pre and post questionnaire (See paragraph 3.5.2.1). The analysis indicated that PSTs displayed basic, medium and complex levels of CK. The average score for basic scientific knowledge dropped from 56.5% to 34.8%, while the average for complex scientific knowledge rose from 30.4% to 52.2%. A closer analysis revealed that approximately one-third of the participants remained at the basic level, whereas about one-fifth advanced their scientific knowledge from basic to complex. For example, in the pre-questionnaire Na. described global warming as follows:

Global warming is an increase in the temperature of the earth, which causes the melting of the snow at the poles and an increase in the water level of the water sources, this warming disturbs the equilibrium of the earth and causes extreme weather and natural disasters.

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Table 4. Scientific change knowledge (CK) levels among pre-service teachers (PSTs) and the average scores for additional CK domains ($N = 24$)

	Basic CL	*Medium CL*	*Complex CL*
Average of additional knowledge types	1.25	2.67	4.25
PSTs (%)	34.8	13.0	52.2

In the post-questionnaire, she answered the same question differently:

Global warming is the result of the emission of greenhouse gases, caused mainly by industry. The emission of these gases into the atmosphere causes heat to be trapped in the earth, increasing temperature. This increase causes the loss of animal habitats, the depletion of natural resources that man uses, the rise in water levels due to the melting of glaciers, and even human life loss" (Complex CL, ecological knowledge, knowledge of natural resources).

Na. referred in the pre-questionnaire to climate change by describing the consequences of this phenomenon without explaining how it appears, but she did so in the post-questionnaire. Moreover, her answer contained two domains of CK.

Different domains of CK and scientific CK

Additionally, we examined different domains of CK, mentioned by participants: ecological knowledge, knowledge about natural resources, consumption behaviour knowledge, environmental contamination knowledge and social-economic knowledge. We conducted a further analysis of the average number of different domains of CK for each scientific CK level (post-results). Table 4 illustrates the level of scientific CK among PSTs and the average of other knowledge domains.

From Table 4, we can see that 52.2% of the participants who mentioned complex scientific CK also used more CK domains to express their ideas. For example, when dealing with food loss and climate change, we asked the participants: "Food production is both a remarkable success story and a source of significant challenges. Discuss this by addressing both its achievements and the issues it faces." Ro. Answered:

In the past, there were no technological means like there are today to produce very large quantities of food. The population is growing, and it is good to have these means, like food engineering. (Social economic knowledge) but the problem on the other hand is that we are destroying our only planet by producing huge amounts of waste that end up polluting the earth (environmental pollution). The entire food production process requires a lot of water resources, and precious land areas (natural resources), causing pollution and increasing the human ecological footprint (environmental pollution). Moreover, the rich get richer and the poor get poorer. There is no fair distribution of the earth's resources, there is no fair distribution of food and only "money talks" if there is no economic profit in it, it is better to throw away the food. This is what the industrialists and everyone in the inner circle think (Social economic knowledge).

Attitudes

Quantitative analysis

The mean scores of attitudes on the pre- and post-questionnaires using the T-test for independent samples were 86.31 ± 10.46 and 90.92 ± 11.05 respectively. Though the attitudes were slightly more positive after the course, this difference was not statistically significant and had a low effect size (0.39).

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Qualatitive analysis

The qualitative analysis, however, revealed an interesting shift in PSTs' attitudes after the course intervention. The analysis of PSTs' statements informed by previous research (Tal & Abramovich, 2013) revealed three main categories. Fourteen percent of PSTs had expressed no explicit concern for the environment, 32% expressed concern based on care for the environment, and 54% declared concern that expressed commitment. For example, referring to the clothing industry, Am. wrote: "The behavioural change should start in every individual that believes it is his/her responsibility to reduce consumption and start living sustainably ... We must change our lifestyle to save and preserve our planet."

Am.'s response was written following a short film presenting the pollution of the clothing industry, the exploitation of workers, including young children, and massive burning of clothing aimed to justify the production of more clothing. This background raised Am.'s awareness and understanding of what must be done both socially and environmentally. Her words sound like a quotation from the film; however, the film itself presented only facts, leaving the audience to interpret the insights on their own.

Another interesting fact is that most PSTs mentioned social justice when dealing with food loss or the clothing industry. For example, Li said the following about food waste:

Instead of throwing it away, food can be collected and sent to hungry people. For example, my 11-year-old son and his friends go once a week to the bakery and the greengrocer and collect leftovers and bring them to the school caretaker, who gives it to the school's needy students. In this way, we are not just reducing food waste but also promoting the value of giving.

Social justice is a value that might illustrate participants' attitudes towards the mentioned topics.

Environmental responsible behaviour

Quantitative analysis

The mean scores of environmental behaviour on the pre- and post-questionnaires using the T-test for paired samples were 58.92 ± 7.83 and 66.76 ± 15.23 respectively. This difference was found significant with $p = 0.025$ and a medium effect size (0.5).

Qualitative analysis

The same tendency was observed in the qualitative analysis, which yielded three categories of behaviour statements (see paragraph 3.5.2.3). The distribution of the answers is presented with examples in Table 5.

As shown in Table 5, PSTs' answers are mostly in the private sphere. For example, while on the pre-questionnaire Gi. mentioned habit-dependent ERB, on the post-questionnaire she expressed EBs she will adopt because now she recognises their effect. As. promotes an environment-friendly lifestyle both in his private life and among his pupils.

In addition, we asked the PSTs to describe at least one ERB they adopted after the course, and whether they have instilled it among family members and pupils. PSTs reported actions in the private sphere, such as wise consumption, saving water and electricity, less plastic and disposable dishes, separating waste, and donating clothes. As for family members, 65% of participants mentioned instilling EBs among family members, explaining the urgent need to act, 33% of the participants described activities with their pupils. For example, Li., writing about her first-grade students: " .... After my lesson on disposable dishes and their impact on the environment, the whole class decided to use regular dishes on the next field trip ... " Another example is Ha. writing about teaching renewable energy through problem-based learning, active learning in which her pupils explore the need for renewable energy and how it can be achieved. Although these examples may not

Table 5. The distribution of levels of environmentally responsible behaviour expression, with examples

	Habit-dependent / unexplained behaviour	*Behaviour-based on "general care" for the environment*	*Specifically explained behaviour motivated by arguments*
PSTs(%)	26	35	39
Example	"I've been saving water and electricity since my childhood. Participating in the course made me aware of waste separation." (Gi.)	"The course and the tasks made me think deeply about what can be done to preserve the planet and save it from climate change. Personally, I've reduced use of disposable dishes and started to take shopping bags when I go shopping." (Wi)	"We buy nutritious food, the amount we need, we exchange clothing with friends and relatives. Teaching my students about the cotton plant I tell them a story about the roles of the coat showing them what can be done with one coat and how this connects to sustainability. I do these things to preserve our resources, to take care of the environment and try to pass it on to my family and pupils." (As.)

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Table 6. Correlations between knowledge, attitudes, and environmentally responsible behaviour scores on pre- and post-questionnaires ($n = 24$)

	Post knowledge grade	*Post attitude grade*	*Post behaviour grade*	*Pre knowledge grade*	*Pre attitude grade*
Post attitudes grade	−0.083				
Post behaviour grade	0.080	.719**			
Pre knowledge grade	0.137	0.174	0.048		
Pre attitude grade	−0.228	.414*	0.263	0.119	
Pre behaviour grade	0.123	−0.042	0.160	0.105	0.298

Note: *$p < 0.05$ **$p < 0.01$.

appear remarkable, they still reflect the increasing awareness among PSTs about educating young children. Hopefully, this marks a small step toward larger changes in addressing global warming.

Interactions: environmental knowledge — environmental attitude — environmental behaviour

A qualitative comparison of different levels of climate knowledge with an expression of attitudes showed that PSTs presenting initial complex climate knowledge had environmental attitudes based on a deep understanding. Their environmental actions involved deep commitment and a holistic approach to improving our planet. The other knowledge levels showed no coherent connection between attitudes and behaviours.

This phenomenon was also observed via quantitative tools. A Pearson correlation analysis (Table 6) indicated that post-course knowledge was significantly correlated with EB: participants with positive attitudes toward the environment ($r = 0.719$, $p < 0.001$) expressed greater EB intentions. A significant correlation was also found between pre-course and post-course attitudes ($r = 0.414$, $p < 0.05$): participants began the course with positive attitudes, and ended it with even more positive attitudes. This correlation indicates that participants who began the course with positive environmental attitudes tended to maintain or even enhance these attitudes following the intervention. This finding implies that the course was effective in reinforcing and deepening existing pro-environmental attitudes among pre-service teachers. The educational intervention appeared to build upon the participants' initial disposition, fostering a more sophisticated and resilient commitment to environmental values

Aiming to understand the predictors of ERB, we conducted linear regression analyses to test the predictive validity of the knowledge and attitudes on ERB before and after the course ($n = 24$). Pre-course environmental attitudes and knowledge ($F = 1.09$, $p > 0.05$) were not predictors of ERB. Post-course environmental attitudes were the only predictor of EB ($F = 5.11$, $p < 0.05$) and accounted for 58.7% of the explained variance (Table 7).

This indicates the importance of causing attitude shifts among lay people and PSTs specifically. However, knowledge learned during the intervention did not significantly predict attitudes or behaviour but was probably the background causing the attitude shift.

Discussion

The current study's objective was to explore the impact of a climate change (CC) intervention course on the CL components: knowledge, attitudes and self-reported behaviour of PSTs. We addressed the challenge posed by Fischer *et al.*, (2022), that analysed how teacher education

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Table 7. Linear regression analyses of the predictive validity of the knowledge and attitudes on environmental responsible before and after the course ($n = 24$)

	Pre-course			*Post-course*		
	B	*SE B*	β	*B*	*SE B*	β
Knowledge	0.53	0.155	0.071	0.130	0.184	0.114
Attitudes	0.217	0.157	0.290	1.097	0.237	0.796*
R2	0.094			0.587		
F	1.089			5.107*		

Note: $^{*}p < 0.05$.

for sustainable development research offers to support teacher education. We focused on designing learning environments, by expanding the framework for testing the effects of the course on teachers. We considered not only the immediate effects on the teachers' knowledge and attitudes, but also their community and their students.

A parallel mixed-methods approach was employed to rigorously analyse pre- and post-course questionnaires, alongside PSTs' responses to various learning activities during the intervention. This methodological integration of qualitative and quantitative data was essential for substantiating the findings and drawing reliable conclusions. Throughout this distance learning course, participants were encouraged to apply a comprehensive skill set, aligning with the multifaceted demands of the Education 4.0 framework (González-Pérez & Ramírez-Montoya, 2022). The analysis demonstrated that the short-term intervention effectively influenced PSTs' CL across all three dimensions — knowledge, attitudes and behaviour — though the degree of impact varied among participants.

Comparing the means of scores of climate knowledge (CK) on the pre-and post-questionnaires using the *T*-test for paired samples, revealed a significant increase in CK following the course. We must note that about 30% of the statements scored high on both pre- and post-questionnaires (See Appendix A). This might imply that participants had some basic previous CK. For almost all the statements, there was a change for the better. For example, "Actions in the private sphere (such as replacing all old light bulbs with fluorescent bulbs) will help reduce the greenhouse gases in the atmosphere" scored 58 on the pre-questionnaire and 83 on the post-questionnaire. Only three knowledge statements showed decrease in knowledge from pre to post questionnaires (Greenhouse gases are like a "Atmosphere blanket." They capture heat and by this cause global warming; The climate crisis refers only to rising global temperatures on earth; Deforestation might cause global warming). Following comprehensive exposure to the course content, students may have developed a more nuanced understanding of the complexities surrounding climate change. While initially they may have accepted general statements at face value (e.g., "there will be a warming trend across the entire country"), the course likely introduced them to more detailed knowledge, emphasising that such trends can vary based on geographic and climatic factors. This deeper understanding may have led to greater critical scrutiny of simplistic statements, thereby reducing the accuracy of their responses in the post-intervention assessment.

Those findings are important due to people's tendency to underestimate their personal influence on global CC and its possible solutions (Groulx, Brisbois, Lemieux, Winegardner & Fishback 2017). The most noticeable and statistically significant increase in CK concerned the Greenhouse Effect, perhaps since it was widely addressed throughout the course. Initial knowledge for this statement was low (38%) but following the course the level of knowledge rose to medium (75%). These quantitative results correspond with the qualitative analysis of the

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open-ended questions in the pre- and post-questionnaires and assignments, which revealed that complex scientific knowledge rose from 30.4% to 52.2%. The identification of various domains of climate knowledge (CK) aligned with the three dimensions of knowledge described by Barbosa *et al.*, (2021) and Frick *et al.*, (2004), which we incorporated into the lessons. Specifically, ecological, natural resources and environmental contamination domains corresponded to system-related knowledge; the socio-economic domain aligned with action-related knowledge; and the consumption domain matched effectiveness knowledge. An important result (table 4) indicated a link between degrees of scientific CK and the acquisition of other domains of CK. About half of the participants who expressed complex CK used more domains of linked knowledge compared to their peers with basic and medium CK. This finding suggests that the ability to express a wide range of linked domains of CK requires extensive core of CK. It sheds light on the importance of providing core science knowledge for the assimilation of widely linked knowledge (Shauli & Baram-Tsabari, 2019). As for behavioural change, the EB scores significantly improved after the course 66.76 compared to 58.92. These scores were lower than the attitude scores, suggesting that raising awareness and feelings towards the environment is effortless, compared to real actions. However, PSTs' statements about their actual actions showed that 39% declared specifically explained behaviour motivated by arguments about the complexity of environmental problems and explicit willingness to act to protect the environment. It is worth noting that all the mentioned behaviour was in the private sphere. This might be due to the statements in the pre-and post-questionnaires or the fact that one of our goals was to show participants that everyone can influence climate change through environmentally-friendly actions (Groulx *et al.*, 2017).

Concerning PSTs' commitment to encouraging ERB among friends, family members and their pupils, 65% of participants did so among family members, explaining the urgent need to act and suggesting ways to act as they were. having acknowledged the importance of immediate personal responsibility. However, only 33% mentioned activities involving their pupils. This might be because PSTs work under the supervision of a mentor-teacher, who controls teaching materials and content. Nevertheless, even for teachers there is a gap between the reality of classroom practices and the rhetoric of education (Abramovich & Loria, 2015; Glackin & Greer, 2021), in our case education on climate change. Pre-service teachers in Israel show a consistent pattern in environmental literacy outcomes. Studies with samples of 214 (Yavetz *et al.*, 2009) and 215 participants (Yavetz *et al.*, 2014) report that while student involvement in environmental behaviours increases, their overall environmental knowledge remains low. Teachers in training struggle to view the environment as a complex system that includes human dimensions. Local discourses have emerged from teacher education policies and professional development settings. These studies state that existing teacher-training programmes provide only limited contributions to developing environmental literacy and worldviews. The environment is framed not solely as an ecological entity but also as a cultural, social and political construct. Such discourses call for a more interdisciplinary approach within teacher-education curricula, highlighting a knowledge-behaviour gap and the need to better integrate environmental understanding into future teaching practices

As for the interaction between environmental knowledge, attitude and behaviour, a Pearson correlation analysis (Table 7) indicated a strong and significant correlation ($r = 0.719$) between attitudes and ERB after the course. This analysis also indicated a low to medium significant correlation ($r = 0.414$) between the attitudes before and after the intervention. This result reflects the importance of exposure to the effects of climate change. In early exposure to environmental issues, pro-environmental attitudes may develop, which might further develop into pro-environmental behaviour in later stages (Gould *et al.*, 2018; Lee *et al.*, 2018; Pitaloka & Aeni, 2024).

Scrutinising participants' statements on knowledge, attitude and behaviour revealed that participants expressing complex CK also had meaningful ERB based on deep understanding of

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the benefit of pro-environmental actions that relied on deep commitment and a holistic approach to improving our planet. These findings are supported by others (Gould *et al.*, 2018; Maartensson & Loi, 2022; Pitaloka & Aeni, 2024). Nevertheless, those who improved from basic to complex climate knowledge referred mostly to attitudes that related to general care for the environment indicating that knowledge acquisition does not necessarily indicate improved environmental attitudes and/or behaviour (Gifford *et al.*, 2014; Gould *et al.*, 2018; Janmaimool & Khajohnmanee, 2019). As for CK dimensions, the literature review did not confirm that acquiring one of the knowledge dimensions will result in the acquisition of other knowledge dimensions as well (Frick *et al.*, 2004). In our case, complex climate knowledge (CK) was associated with a greater number of other CK domains. Additionally, albeit not statistically connected, there was an interaction between having complex CK and the acquisition of meaningful EB accompanied by solid attitudes. Still, the knowledge had to be assimilated before it could influence environmental attitude and behaviour. These findings confirm those of previous research among pupils (Van de Weterbing *et al.*, 2022), college students (Zeng et al., 2023) and lay adults (Dhir *et al.*, 2021). Van de Weterbing *et al.*, (2022) concluded from their review of recent literature that environmental education has a positive impact upon the environmental outcomes of children and adolescents. Zeng *et al.*, (2023) analysed the relationships between environmental knowledge, risk perceptions and concerns among students in China and demonstrated that environmental knowledge significantly influences environmental concerns, which in turn affects pro-environmental behaviours. Dhir *et al.*, (2021) findings suggest that enhancing environmental knowledge, trust and concern can positively influence consumers' attitudes and behaviours towards green apparel. Furthermore, this technological educational experience might enhance the pre-service teachers to incorporate the content and the technology in their teaching classes (Das & Meredith, 2021).

On the other hand, the analysis reveals that participants with basic climate knowledge had environmental attitudes and behaviour based on general care for the environment (medium score). This implies that knowledge is not the only factor that influences behaviour. Similarly, Geiger *et al.*, (2019) found that certain domains of general knowledge (e.g., basic ecology, climate . . .) were responsible for a small proportion of variance in environmentally significant behaviour. Other variables, beside knowledge, might be involved: beliefs, economic situation, social norms, infrastructure, old habits and values (Abramovich & Loria, 2015; Heimlich & Ardoin, 2008; Maartensson & Loi, 2002). Stern (2000) developed the value-belief norm (VBN) theory, suggesting that values might lead to an ecological worldview and later to the evolution of beliefs — awareness of consequences and ascription of responsibility — that will lead to greater pro-environmental personal behaviour. In our study, though not specifically measured PSTs' values, most participants referred to social justice, which could be identified as a value that evolved into EB.

Conclusion

This study evaluated PSTs' CL and ERB before and after a short intervention. The course significantly enhanced PSTs' CK and behaviour, with attitudes already high at the start. Despite the well-known gap between attitudes and behaviour (Kollmuss & Agyeman, 2002), our findings suggest that positive attitudes might lead to improved pro-environmental actions when coupled with a focused intervention.

The data revealed that scientific complex CK forms the foundation for more domains of CK. While most PSTs applied their learning in personal contexts, fewer transferred it to their teaching, potentially due to curriculum constraints or because they were not taught how. Future research should investigate how PSTs address climate issues once they have more autonomy in their teaching.

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In summary, even a brief intervention can effectively enhance CL across knowledge, attitudes and behaviours. This supports the need for integrating such courses into teacher education programmes to foster long-term, pro-environmental change.

Limitation

This study faced several notable limitations that warrant consideration. First, the sample size of 36 pre-service teachers (PSTs) restricts the generalisability of the findings to broader populations or different educational contexts. Additionally, the reliance on self-reported measures for attitudes and environmentally responsible behaviour (ERB) may introduce biases, such as social desirability or inaccurate self-assessment. The short duration of the intervention, consisting of only five asynchronous lessons, might not have been sufficient to instil long-term behavioural changes or deeply embedded knowledge. Furthermore, the study's emphasis on PSTs' personal and familial contexts, as opposed to their professional teaching practices, limited insights into how CL translates into classroom instruction. Finally, while the mixed-methods approach provided depth, the absence of longitudinal follow-up data precludes evaluation of the intervention's sustained impact over time. These limitations suggest that future research should expand the sample size, incorporate objective measures and examine long-term outcomes in diverse educational settings.

Supplementary material. The supplementary material for this article can be found at https://doi.org/aee.2025.10047

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Ethical standards. This study was conducted in accordance with the ethical research principles outlined in the Declaration of Helsinki (2013), including respect for confidentiality, informed consent, and data protection. All participants were fully informed about the nature of the research and provided their consent for their data to be included. To ensure privacy, all data have been anonymized. The researchers adhered to these ethical principles throughout the study.

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Author Biographies

Dr Anat Abramovich, received her BSc and MSc in agricultural engineering from the Technion (Haifa), specialising in waste leachate treatment. She earned her PhD from the Faculty of Technology and Sciences at the Technion (Haifa), specialising in environmental education. Dr Abramovich had taught mathematics for 22 years, and for 12 years, she combined it with teaching high school environmental science. She is the head of the Israeli Center for Scientific Technological Education, and a lecturer at the Gordon College of Education.

Dr Sophie Shauli (B.Sc., Hebrew University; M.Sc. and Ph.D. Technion) is a postdoctoral researcher in the department of education and psychology at The Open University of Israel. She is a lecturer and the head of science education department at Gordon College, and she holds a teaching position with SHEMA, NGO aiding youth with deafness or hearing impairment, supporting students with hearing difficulties in inclusion educational programmes. Main research interests include public engagement with science, enviormental education and inclusion of students with disabilities.

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