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Teacher continuous professional development in climate change education: Analyzing teachers' perspectives

Martin Bascopé[a,b] (iD), Rukmini Becerra[a,b], Daniela Salazar[a], Andoni Arenas[c], Roberto Morales[c], Cristian Merino[c], Delia Cisternas[c] and Paulina Ampuero[d]

[a]Campus Villarrica, Pontificia Universidad Católica de Chile, Villarrica, Chile; [b]Centro UC de Desarrollo Local (CEDEL UC), Pontificia Universidad Católica de Chile, Villarrica, Chile; [c]Pontificia Universidad Católica de Valparaíso, Valparaíso, Chile; [d]Universidad de Santiago, Santiago, Chile

ABSTRACT

This paper explores teacher continuous professional development (CPD) in climate change education, focusing on two programs implemented in Chile. Combining a literature review with an analysis of materials produced by teachers, the study highlights the innovative approach of examining CPD programs through teacher-created materials. Teachers in both programs designed educational activities on climate change, forming the research core. Using the "In-vivo" coding technique, the study identifies the presence of key elements for effective CPD: active learning, collaborative learning, outdoor and place-based learning, culturally relevant teaching, sociopolitical perspectives, and emotional responsiveness. The research underscores the need for transdisciplinary integration and contextualized education. It offers recommendations for enhancing existing CPD programs and developing new ones, emphasizing the importance of combining scientific approaches with local knowledge to address the complexities of climate change education. The findings aim to inform the global community and support the integration of climate change education into school curricula.

Introduction

This article explores educational approaches for understanding complex phenomena, focusing on climate change education as an exemplary topic. It combines a literature review with a detailed analysis of materials produced by teachers in four versions of two distinct continuous professional development (CPD) programs on climate change education in two regions of Chile. This study presents an innovative approach to analyzing CPD programs, emphasizing not only the predefined syllabus and course materials but also the materials produced by teachers during the courses. Both programs culminate in participants designing educational activities on climate change, which constitute the core of this research. Teachers' perspectives on implementing climate change education are compared with recent literature, providing directions for further analysis of CPD programs, recommendations for planning climate change education experiences, and guidance for developing additional professional development opportunities in this vital area (Table 1).

The methodology for analyzing the programs employed the "In-vivo" coding technique (Saldana, 2009), based on a framework informed by key research findings on climate change education and CPD programs. This method offers a valuable tool for CPD programs in various contexts, enhancing understanding of how climate change education is planned and executed. Moreover, the results of this research can inform the creation of new climate education programs or the enhancement of existing ones, based on the findings and analytical methods proposed.

Table 1. summary of the article.

Purpose of the article	Framework for the analysis	Coding themes/dimensions	Findings
This study aims to contribute to the ongoing development and refinement of climate change education and CPD programs. Provide an updated literature review regarding international CPD programs on climate change Provide an analysis of the comparison between teachers' perspectives on implementing climate change education and recent literature on the topic	**Transversal principles** a. Teaching complex phenomena b. Transdisciplinary learning opportunities **Characteristics of CPD programs on CC found in the literature** a. Active learning methodologies b. Collaborative learning c. Experiences in outdoor and place-based learning d. Culturally relevant teaching e. Sociopolitical perspectives f. Emotionally responsive	**Teaching materials:** a. What is being taught? b. Who is teaching it? c. How is it being taught? d. What knowledge, attitudes, competences, and skills are being promoted? e. Where is it being taught? **Teacher barriers and perspectives:** a. What were the main barriers to implementing the project b. Do they include socio-political perspectives? c. Do they consider socio-emotional aspects? d. Is the perspective of children and young people included in the project?	Major focus on the problems related to climate change (diagnostic), rather than path for action (mitigation or adaptation). Teachers and families are the main actors in charge of teaching. Multimedia and developing communication products are the main teaching strategies The school classroom, yard and the school's surrounding are the main spaces where the teaching occurs. Lack of student competencies, lack of time implementation, teacher collaboration, and interdisciplinary planning being the most notable issues. Socio-ecological justice, the socio-emotional and the students' perspectives on CC were almost absent.

After examining the main insights gained from conducting climate change CPD, several critical questions regarding climate change education emerged, which this article will address: How do we transit from engaging interventions to establishing CPD programs on climate change? What is the role of teacher collaboration? Can schools integrate local knowledge and actors? How can we integrate knowledge and connect it with real-life situations? Do we consider students' perspectives on climate change? What insights do they offer on socio-ecological or intergenerational justice? By addressing these questions, this study aims to contribute to the ongoing development and improvement of climate change education and CPD programs, in other words a more comprehensive question this research aims to answer, learning from the experience and voices of Chilean teachers is: What are the characteristics, methodologies, and actors needed to be considered for teacher CPD programs on climate change?

Facing complex challenges: The limits of subject-based education

In 1974 E.F. Schumacher in his book "Small is Beautiful" introduced the concepts of "convergent" and "divergent" problems, developed by the physicist and mathematician G.N.M. Tyrell (Schumacher, 1973). These concepts were used to describe issues that can be solved logically alongside those that cannot. When faced with divergent problems and complex challenges like climate change or socio-ecological problems, the positivist approach, reductionism, and hyper-specialization of academic and professional knowledge can occasionally fall short of offering an acceptable solution. Climate science is a hard thing to understand and communicate; it is clearly a topic that cannot be solved linearly or logically, with many layers, causes and multiple consequences in different levels.

Besides, climate change is a complex and sometimes scary topic to address. On the one hand one may encounter barriers, considering the impact that the apocalyptic narratives can have on children and youth. On the other hand, even if those barriers disappear and the educator is willing to deal with all the complex emotions involved in the journey, it is hard to find a clear path to navigate the complex system behind climate change (Ojala, 2015; Verlie et al., 2021).

There is another daunting challenge present in every intent to conduct climate change education in schools or kindergartens: How does this fit the curricular guidelines? First, the topic is relatively new and hardly mentioned in the Chilean curricular guidelines (MINEDUC, 2012, 2018; Salinas et al., 2022). Some concepts and contents regarding climate and its subsystems can be found in the natural and social sciences guidelines, isolated and independent from each other. Nevertheless, we will delve deeper into the argument that climate change education is not just about climate science content or understanding "about" climate change. We will frame it as a set of skills, knowledge, and attitudes for coping with the challenges that climate change will bring in the future and finding transdisciplinary ways to mitigate or adapt to its consequences.

Secondly, we will argue that climate change has many ways of manifesting in everyday life; with diverse consequences and can be situated in the intersection of many fields of knowledge, across curricular guidelines, breaching the structures that curricular guidelines provide to teachers (Salinas et al., 2022). The existing curricular structure, divided into disciplines, can be of little avail to address these complex matters, and there is a need for pedagogical approaches and professional development opportunities for teachers to support disciplinary integration, for climate change education to be introduced in schools.

To address the loss of meaning that occurs when dealing with complex issues, this article argues that transdisciplinary integration in educational opportunities can help overcome an instrumentalist perspective of these challenges, integrating not only across disciplines (interdisciplinarity), but also validating other local and diverse ontologies and epistemologies for a broad and relevant understanding of the challenges of climate change (transdisciplinarity).

Transdisciplinary learning opportunities: A dual integration process in

We propose early implementation of transdisciplinary learning approaches, that combine a scientific approach (from both natural and social sciences) in dialogue with other nonscientific sources of knowledge. Our assertion is that we are facing an urgent need to open paths to new fields and worldviews to properly address this complex issue.

Hence, we are facing a challenge of integration, which we understand as being two dimensional. First, there is a need for integration across disciplines, proposing opportunities centered on topics that consider curricular objectives from different existing disciplines, to understand the complexity of climate change from diverse perspectives. Secondly, there is another integrational challenge in climate change education, namely its connection with real-life situations, not just to make it more tangible and solution oriented, but also to define a starting point. The global perspective hinders the understanding of the phenomenon on a human scale and global challenges often fail to motivate students and teachers due to their distance and inability to make a significant difference.

Simply stated—and to differentiate it from interdiscipline, transdiscipline at the school level seeks to combine several disciplines, along with other external sources of local knowledge (e.g. indigenous, peasant, traditional) that are not traditionally considered in schools. This scope is aligned with a cross-cutting focus present in many intergovernmental educational frameworks, which consists in connecting educational opportunities to real-world circumstances, exposing schools to their context, and supporting the implementation of educational opportunities based on facts, with concrete results, tangible outputs, and valuable outcomes (OECD, 2018b, 2018a; UNICEF, 2016).

Framing our pedagogical approach as transdisciplinary will be helpful to understand our position as researchers, and the way we understand climate change education. Thus, the analysis of the scientific literature on the topic and the critical assessment of teacher CPD programs will be based on this transdisciplinary approach. This implies a process of epistemological transformation regarding climate change and the ability to teach it: moving from an epistemological perspective of curricular school science, focused on an ontological dimension of the problem (e.g., the physics of Climate), to other levels of understanding and reality that bring us closer to a holistic approach such as that developed by Tolppanen et al. (2017) or Cantell et al. (2019), and the transdisciplinary perspective (Nicolescu, (s.a); Morin, 1984, 1990).

Before presenting the results of this study, it is important to delve deeper into our understanding of place-based education, specifically in an indigenous context, since our research and work was conducted in Chile. Our colonial history and the main narratives regarding human-nature interactions are key not only to understanding the context, but also to providing a useful framework for climate change education elsewhere, considering the importance of learning from intercultural and indigenous approaches.

What should a CPD program on CC look like? Literature review

After a careful review of the CPD literature on climate change, we highlight the main characteristics required of these kinds of programs. The review studied research indexed in scientific journals (Web of Science and SCOPUS) as well as recent books and chapters, for incorporating global south perspectives. Most of the research we found originated in Europe, Australia and North America, so a couple of African and South American experiences were considered, although there is clearly a gap in research on this topic that needs to be covered by learning from relevant experiences. Six cornerstones for the implementation of CPD in climate change are highlighted in the following paragraphs, which will be used to contrast the empirical findings and provide relevant recommendations for the international community.

Active learning methodologies

Active learning methodologies are important because they involve teachers in interactive, hands-on learning activities. This methodology is in line with the latest breakthroughs in the field of education. Recent meta-analysis showed an effect of active learning methods on positive attitudes and better performance in topics such as STEM, environmental education, social sciences, and humanities (Arık & Yılmaz, 2020; Freeman et al., 2014; Kozanitis & Nenciovici, 2023; Tutal & Yazar, 2022). In teacher professional development, several studies recommended these methodologies, confirming that teachers who actively participate in their own learning are better able to reproduce these strategies in the classroom, which in turn fosters student involvement and an environment where themes related to climate change are explored through dialogue, experiments, and problem-solving activities (Hestness et al., 2017; Mallon, 2015; Park & Park, 2020; Schudel et al., 2021; Thenga et al., 2020).

Collaborative learning

Collaborative learning is crucial for successful teacher professional development related to climate change, for several reasons. Teachers can gain access to a variety of viewpoints, ideas, resources, and best practices from their different fields by participating in collaborative learning experiences (Li et al., 2021). Furthermore, collaborative learning emphasizes that combating climate change requires a team effort by fostering a feeling of community and shared responsibility. Many studies on Climate Change CPD, emphasize the importance of collaborative learning, for teachers to be able to co-create educational resources, come up with creative ways to teach about climate change, and assist one another in putting climate-focused curriculum projects into action by working together. In addition, this collaborative approach fosters a collaborative culture in educational institutions and communities, which is crucial for bringing about long-lasting change in the field of climate change education (Favier et al., 2021; Jeong et al., 2021; Li & Krasny, 2019; Schudel et al., 2021).

Experiences in outdoor and place-based learning

Experiences in outdoor and place-based learning are crucial for establishing the connection between climate change education and concrete, everyday situations. Teachers who interact with their local surroundings or experience learning in natural settings are better able to provide their students with similar possibilities (Conlon et al., 2025 ; Drewes et al., 2018; Olawumi et al., 2023; Park & Park, 2020). This

feature encourages a more intimate relationship with the environment, fostering stewardship and assisting educators in illustrating how climate change is affecting communities, thus opening the discussion on the importance of culturally relevant teaching for climate change education (Favier et al., 2021; Nation & Feldman, 2022; Roehrig et al., 2012).

Culturally relevant teaching

Culturally relevant teaching is essential for addressing climate change because it recognizes the varied viewpoints, and experiences that people from different cultural backgrounds bring to the discussion of environmental concerns (Kern et al., 2017). Teacher professional development ensures that climate change education connects with students' lived realities and cultural contexts by integrating culturally relevant approaches. Because of the regional and cultural variations in the impacts and responses to climate change, this component is especially important. Through the incorporation of indigenous knowledge, local wisdom, and culturally relevant examples into the curriculum, educators may improve the accessibility, relevance, and engagement of climate change education for every student (Roehrig et al., 2012). Additionally, learning that is culturally relevant builds empathy and understanding, respect for differing viewpoints, and the confidence children need to take an active role in tackling climate change in their local communities.

In Chile, studies of the Mapuche learning system (the main indigenous population in the country) have examined interactions between students and teachers and discovered that the indigenous teaching are scarce. As opposed to formal methods, Mapuche learning emphasize exchange knowledge in public places and during daily life (Quilaqueo et al., 2010; Quintriqueo Millán et al., 2012). Parents and other adults are knowledge managers in children's environments by serving as role models for how to apply information through play, or in the routine tasks that come with living in a community and at home (King & Schielmann, 2004; Llanquinao Trabol, 2009). The autonomy of children in handling the events they encounter is prioritized in this adult-child connection, and few are offered (Ibáñez-Salgado, 2015). In this sense, active learning, collaborative and place-based methodologies, are aligned with indigenous traditional ways of learning, and can be helpful in reshaping the way climate education is taught.

Sociopolitical perspectives

Sociopolitical perspectives on climate change challenges must also be considered in teachers' CPD. Professional development with a social justice focus, highlights the links between climate change and general social challenges like inequality, environmental justice, and human rights (DEI, 2009; Drewes et al., 2018; Ennes et al., 2021). Teachers can learn how marginalized populations are disproportionately affected by climate change and how education can be a tool for advocacy by investigating these links. By encouraging educators to include conversations about justice, equity, and shared responsibility in their lessons, they promote a more inclusive and socially conscious method of teaching about climate change. This is a crucial characteristic for CPD programs on climate change to ensure cultural relevance and equitable opportunities for understanding complex problems, including their socio political repercussions (Leonard et al., 2016). A recent study emphasizes the concept of "critical emotional awareness" in climate change education, connecting the sociopolitical perspective with its emotional implications (Ojala, 2023).

Emotional responsiveness

Emotionally responsive professional development acknowledge that intense feelings like fear, despair, and anxiety can be triggered by climate change (Chawla & Gould, 2020; Ojala, 2012, 2015; Verlie et al., 2021). By fostering a secure and compassionate learning atmosphere, educators who have participated in CPD programs on emotional responsiveness can better assist their students in processing these feelings, navigating their concerns and responses constructively by addressing the emotional components of climate change (Bryan, 2020; Trott, 2022). This could encourage resilience and develop a sense of hope and empowerment in the face of environmental anxieties.

The emphasis on emotions and sociopolitical aspects of climate change was especially relevant in the literature review. Due to its importance, we decided to examine its presence in teacher products after participating in the CPD programs, even it was not an emphasis of analyzed programs, to see if these aspects were considered by teachers nonetheless. Further, discussion will be held in the following sections to understand the programs analyzed, the data collected, coding process, findings and discussion.

Data sources and context of the analyzed programs

Two programs created in different regions of Chile, were analyzed for this paper, both designed and created by different teams that decided to collaborate in a joint effort to improve climate change education by cross-checking their CPD programs. Both programs developed educational resources to foster learning on sustainability and climate change and used active methodologies to enhance the competences of in-service teachers to address climate change topics. The programs were implemented between 2021 and 2023 at two universities, one in the center and another in the south of Chile. Both programs have published an open call for in-service teachers to participate in the initiatives (free of charge).

Two regional Universities, represented by initial teacher education professors, participated as creators and facilitators of these programs, one located in the central coast and another in the southern mountains of Chile. Both programs were created separately, implemented in different geographical contexts, without communication between the universities until after the programs ended. The idea of comparing diverse programs under the same study gives more strength to this research and helps to understand commonalities and possible areas of improvement that might be present in other programs, not only in Chile, but elsewhere. The specifics of each program are detailed in the following paragraphs.

Sustainability lighthouse

The Sustainability Lighthouse program focuses on Design Thinking and Project-based learning applied to design solutions to local sustainability problems, based on scientific research. It is designed to equip in-service teachers with the knowledge and practical tools required for implementing project-based learning (PBL) methodologies in their classrooms. One of the program's key objectives is to facilitate the application of PBL methodologies through the creation and implementation of school research projects with students, aligned with the specific territorial context of each educational institution. The course comprised 48 h of instruction, divided into three modules. The first module focused on the introduction and planning of school research projects with PBL methodology. The second module addressed the co-design of the research methodology and streamlining with the national curriculum. The third module focused on the presentation of the research results. Additionally, part of the learning objectives included the co-evaluation and feedback of the classroom experience. A total of 52 teachers participate in the two versions considered for this article, of this CPD program carried out during 2023.

Climate change continuous professional development: The MICA program

The program's aim was to equip teachers with theoretical, conceptual and practical tools to enable them to act as agents of change and knowledge mobilizers in their schools and communities, in relation to the implications of climate change in their territory.

The CPD program consisted of 140 h of face-to-face, virtual and field-based learning. The program was structured in four main modules, covering a range of topics related to climate change: global aspects, local issues, the use of technological tools, strategies for teaching climate change and possible local actions for climate change mitigation and adaptation. One of the objectives of the program was to facilitate the co-construction of learning scripts relevant to the educational context of the participants, or a poster with a school-community project for later application in the classroom. Two versions of this program were considered for analysis. The first version was carried out during the second semester of 2022 with 28 teachers of different subjects and school grades in three municipalities in southern Chile. In the second version, carried out between the end of 2022 and the beginning of 2023, 25 teachers of different subjects

and school grades from two municipalities in Central Chile participated. In this latter version, the diploma was complemented with the MICA Kit (Interactive Map for Climate Change Education, (https://specto.pucv.cl/aplicaciones-mica/), as a technological tool to foster a connection between schools and the latest advancements in climate science.

Sample and methods

Analyzed teaching materials

In both CPD programs, one of the outcomes was the planning and implementation of projects led by teachers. Furthermore, a logbook was created for the Sustainability Lighthouse program to facilitate the collection of teachers' reflections on the challenges and achievements encountered throughout the implementation. Table 2 describes the analyzed materials.

All collected materials were evaluated; there was no sampling of the created materials for the courses. All materials were generated by educators during the execution of the two programs, as part of their assessment, and all were taken into account. The sole selection process was conducted for the involvement of educators in the courses. The participant schools in the sustainability lighthouse were chosen in conjunction with the regional environmental certification department of the Ministry of Environment, while students for the other program were selected in collaboration with the local public educational departments involved. The selected participants were from schools with prior experience or interest in climate change and sustainability issues.

Several biases may emerge when evaluating teachers' self-reported lesson plans and resources related to climate change. Social desirability bias frequently compels educators to present their methodologies in a more advantageous manner, emphasizing "ideal" strategies over their true practices. Selection bias frequently occurs, as educators may highlight their most successful instances while disregarding less effective or standard approaches. Moreover, experiential bias may cause more seasoned educators to assert "optimal outcomes" with confidence, whilst their less experienced counterparts may underestimate their contributions. These self-reports frequently reflect idealized teaching rather than practical implementation.

To achieve an accurate comprehension, it is essential to corroborate self-reports with witnessed effective methods and concrete materials. Consequently, we examine both plans and executed activities, thereby closing the divide between intentions and classroom reality. Furthermore, the findings of this research integrate "ideal planning" with executed actions, therefore the potential deficiencies and obstacles identified emerge from the experiences of teachers in these actual examples, providing avenues for transformation grounded in realistic and educator-generated contexts.

Methodology

Coding process

The teaching materials produced in both programs were analyzed using the "In-vivo" coding technique for the first coding cycle, aimed at prioritizing the voices of the participants (Saldana, 2009), and pattern coding for the second coding cycle. During the first coding cycle, overrepresentation of data was mitigated by selecting only one code per document, even if that code was mentioned multiple times in the document. However, at the end of the second cycle of pattern coding, as codes are grouped into larger patterns. Therefore, the final coding reveals which topics were addressed in greater depth, rather than simply reflecting the number of documents where the pattern was present. The coding was carried out independently by two of the authors and corroborated by a third author to ensure the reliability of the data.

The framework on which the coding is based seeks to identify the issues that teachers address after participating in a CPD program on climate change education, and what characterizes the classroom work that is then carried out. Following the literature review on "What should a CPD program look like?", four types of products were coded according to questions based on the previously identified highlights and divided into three dimensions and subdimensions as presented in Table 3.

Table 2. A description of the analyzed teaching materials.

Teaching Products	Description	Authors	CPD program	N (49)
Portácoras - Mix between a Portfolio and logbook of the implementation of school projects (Word)	This document is a combination of a portfolio and logbook. It includes a matrix for teachers to record their progress during the implementation of the project, as well as guidelines for facilitating the reflections of the teaching group. The reflections sought to identify the principal obstacles encountered during the implementation process, as well as the challenges that were identified, the collaboration that would be beneficial in this context, the successes achieved, and other pertinent information.	Groups of 2 to 4 teachers.	Sustainability lighthouse	16
Final project-based learning showcase (PPT)	The presentation, delivered on the last day of the program, provided an overview of the research conducted. The presentation identified the problems addressed, the objectives, the curricular linkage, the methodology, the results, and the conclusions.	Groups of 2 to 6 teachers.	Sustainability lighthouse	4
Learning scripts (PDF)	The sequence is constructed from a design matrix that considers the educational level at which the activity is implemented, learning objectives, subjects, evaluation indicators, student activities, teacher activities, and resources and materials to be used. A total of three to four sessions are planned for each pedagogical sequence.	One teacher.	Climate change education diploma	23
Poster presentations (PDF)	A poster presentation of the preliminary project proposal put forth by the teaching group. The document outlines the key elements of the project, including a summary of the problem, objectives, background, design, expected results, conclusions, and projections.	Groups of 2 to 6 teachers.	Climate change education diploma	6

Table 3. Dimensions for the coding process.

1) What characterizes the teaching materials:	1.1) What is being taught? 1.2) Who is teaching it? 1.3) How is it being taught? 1.4) What knowledge, attitudes, competences, and skills are being promoted? 1.5) Where is it being taught?
2) What were the main barriers to implementing the project?	Identification of the main obstacles that teachers mention when implementing their climate change education plans.
3) Presence of perspectives identified as absent in the literature review	3.1) Do they address aspects of socio-ecological justice in their proposal? 3.2) Do they consider socio-emotional aspects? 3.3) Is thee perspective of children and young people included in the project?

Codes generated from teaching materials

After the emergent coding analysis of the 49 teaching materials, a total of 652 codes were generated, the detail is presented in Table 4.

The results will be analyzed considering each subdimension investigated and the groupings of codes by patterns generated in the second coding cycle. Therefore, on the graphs' X-axis, the numbers do not correspond to the number of documents, but rather to the number of times a specific code appears in the documents. This facilitates the identification of the most recurrent or most deeply explored themes. During the discussion, examples of teachers' voices obtained in the first coding cycle using the "*In Vivo*" technique will be provided. This will be done to highlight and exemplify the groupings of codes worked on.[1]

Table 4. Number of codes obtained for each question, according to the type of teaching materials analyzed.

Dimension	Subdimension	Portácoras	Posters	Final project based learning showcase	Learning scripts	Total
1) What characterizes the teaching materials?	1.1 What is being taught?	2	11	12	61	86
	1.2 Who is teaching it?	2	5	7	18	32
	1.3 How is it being taught?	11	20	25	119	175
	1.4 What knowledge, attitudes, competences, and skills are being promoted?	3	18	22	99	142
	1.5 Where is it being taught?	3	5	9	26	43
2) What were the main barriers to implementing the project?	2. What were the main barriers to implementing the project?	63	0	2	0	65
3) Did they include socio-political perspectives?	3.1 Do they address aspects of socio-ecological justice in their proposal?	0	5	6	23	34
	3.2 Do they consider socio-emotional aspects?	1	5	6	21	33
	3.3 Is the perspective of children and young people included in the project?	6	5	6	25	42
	Total	**91**	**74**	**95**	**392**	**652**

Findings

What characterizes the teaching materials?

The subsequent paragraphs summarize descriptive results highlighting the primary characteristics of the revised teachers' materials. The subheadings correspond to the primary domains of the coding process, presenting a graph at the conclusion of each section that illustrates the coding results.

What is being taught?

Regarding the principal subjects addressed in climate change teaching, it was observed that these are predominantly oriented toward issues relevant to the territories where the teachers are based. The most prevalent category was "Pro-environmental practices and adaptation" (19.8%), encompassing topics such as waste reuse, responsible consumption, native reforestation, and citizen participation. Following this, "Water scarcity and climate change" (17.4%) and "Biodiversity, ecosystems, and climate change" (18.6%) emerged as significant themes, alongside other categories addressing the effects of climate change on various areas and ecosystems. However, when grouping the categories related to the impacts of climate change, it was found that 69.8% of the topics focused on impacts, while only 19.8% emphasized adaptation or mitigation actions. This indicates a stronger focus on the problems related to climate change rather than actionable paths like mitigation or adaptation (Figure 1).

This predominance of teaching about impacts over strategies for mitigation and adaptation has been documented in specialized literature. For instance, recent studies highlight that while climate change education has advanced awareness of negative effects, there remains a need to strengthen training in adaptation and mitigation practices to foster effective action (Ramos de Robles et al., 2025). Furthermore, it has been pointed out that integrating indigenous and local knowledge into education can enrich adaptation strategies to climate change by providing practical and culturally relevant perspectives (Zhai et al., 2025).
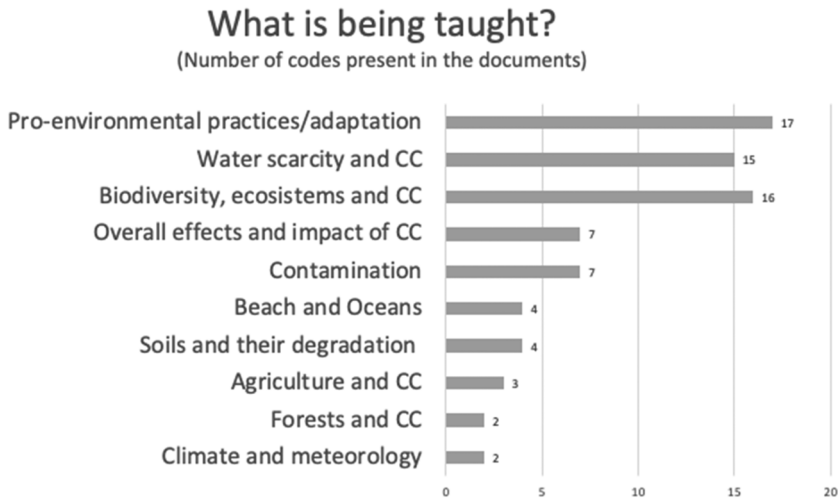
What is being taught?
(Number of codes present in the documents)

Figure 1. Code counting on "What is being taught?"

Therefore, it is essential to balance the teaching of climate change impacts with education on concrete mitigation and adaptation actions. This approach fosters a type of education that not only informs individuals about the issues but also empowers communities to take proactive measures in addressing the current environmental challenges.

Who is teaching it?

When analyzing who teaches climate change education, it was observed that in half of the cases, the teacher was the primary actor delivering this instruction, followed by the family, which accounted for 15.6%. Notably, community social actors, such as municipal environmental officers and representatives from the Ministry of the Environment, as well as rural actors like muleteers, goatherds, and farmers, were each represented with 9.6%. This diversity of educators highlights the multifaceted nature of environmental education, with contributions extending beyond formal educational settings to include community and rural perspectives, enriching the learning process.

This aligns with findings in the literature that emphasize the critical role of teachers as primary educators in environmental topics (Heimlich & Ardoin, 2008) and the importance of incorporating local and indigenous knowledge to make education contextually relevant (Agrawal, 1995). Moreover, studies have noted the value of community involvement and informal actors in environmental education, which foster collaborative learning and holistic understanding (Ballantyne & Packer, 2009) (Figure 2).
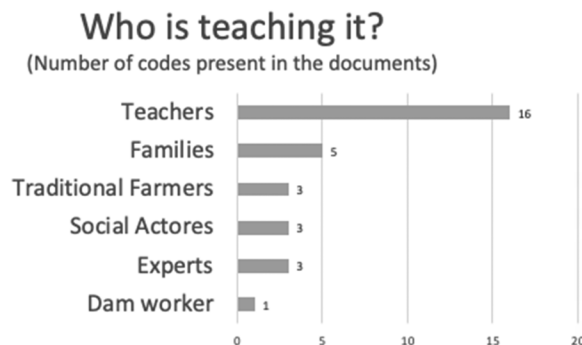
Who is teaching it?
(Number of codes present in the documents)

Figure 2. Code counting on "Who is teaching?"

How is it being taught?
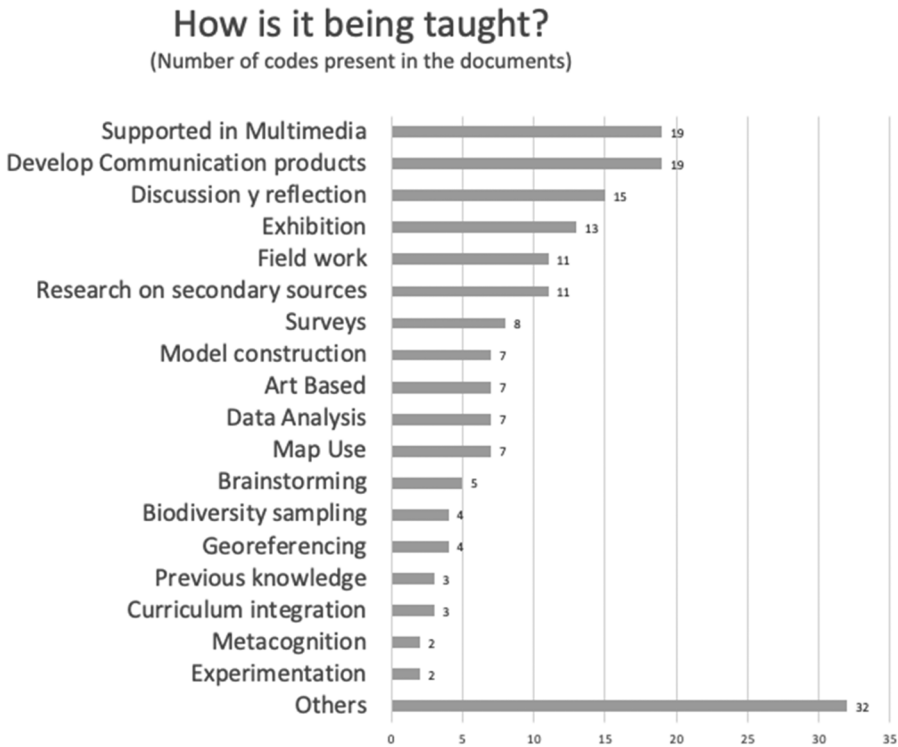(Number of codes present in the documents)

Figure 3. Code counting on *"How is it being taught?"*

How is it being taught?

"Supported by multimedia" was the most represented method with 10.9%, highlighting the use of satellite images and watching videos. This was followed, with the same percentage, by 'communication products' with informative posters, infographics, audiovisual productions, among others, mainly aimed at disseminating the results of the school project. Most of these products were circulated within the educational institution. In the third place, in terms of teaching methods, the methodologies that lead to "Discussions and reflections" (8.6%), such as discussions, round tables with key actors, group discussions and reflections in pairs or groups, stand out (Figure 3).

What knowledge, attitudes, competences, and skills are being promoted?

The primary skills promoted by the teaching materials are research skills (12%), which include formulating questions, gathering and analyzing data, and drawing conclusions. These are followed by skills related to planning, selecting information, and predicting, which support systematic thinking and decision-making. These skills align with the higher-order cognitive processes outlined in Bloom's taxonomy, such as analysis, evaluation, and creation. Other notable skills include describe-identify (10.6%) and understand-know-recognize (8.5%), which correspond to foundational knowledge and comprehension levels within Bloom's framework (Figure 4).

Where is it being taught?

Only 34.9% of the proposals focus on the educational process within the classroom. The remaining 55.7% extend the educational space beyond the classroom, reflecting a diverse range of learning environments. These include the school and its immediate surroundings (25.5%), gardens and greenhouses (9.3%), and fieldwork in various locations such as wetlands, universities, forests, beaches, and shopping malls (21%). Additionally, 4.7% of the codes fall under the categories of "unidentified land" or "absent."

Knowledge, competences, attitudes and skills
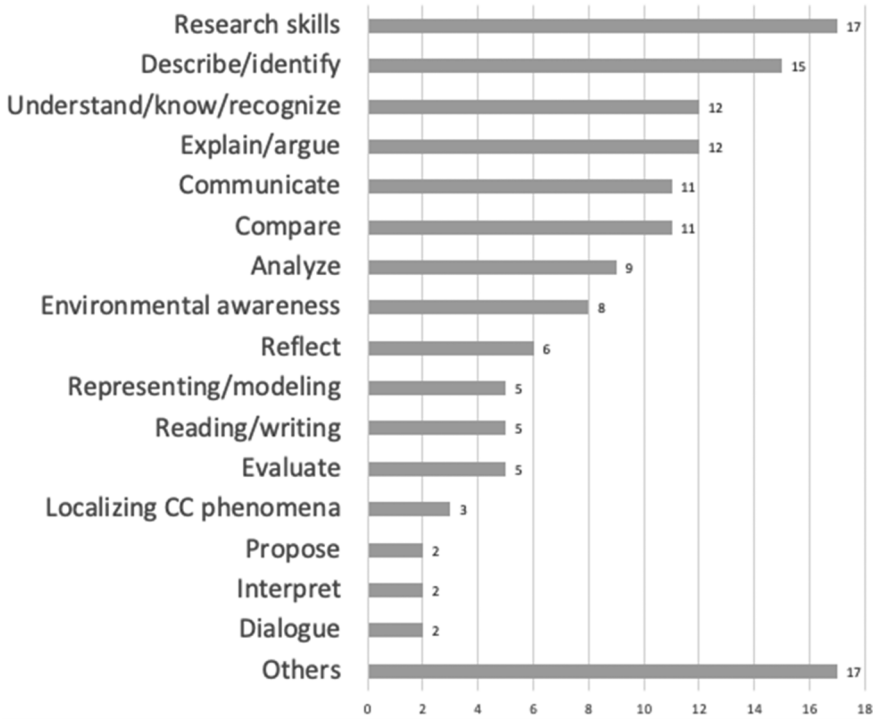### (Number of codes present in the documents)

Figure 4. Code counting on "What knowledge, attitudes, competences, and skills are being promoted?"

Where is it being taught?
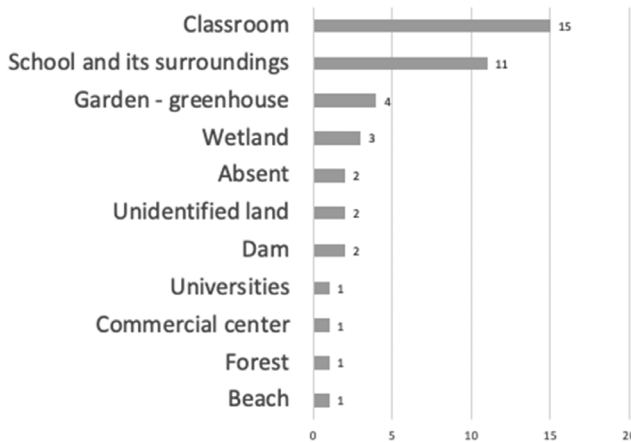### (Number of codes present in the documents)

Figure 5. Code counting on "Where is it being taught?"

This trend highlights the growing emphasis on outdoor and experiential learning in environmental education, which promotes deeper engagement and practical understanding of ecological systems (Dillon et al., 2006). Research indicates that extending learning beyond the classroom fosters a sense of place, contextualizes learning, and strengthens environmental attitudes and behaviors (Rickinson et al., 2004) (Figure 5).

Difficulties in implementation
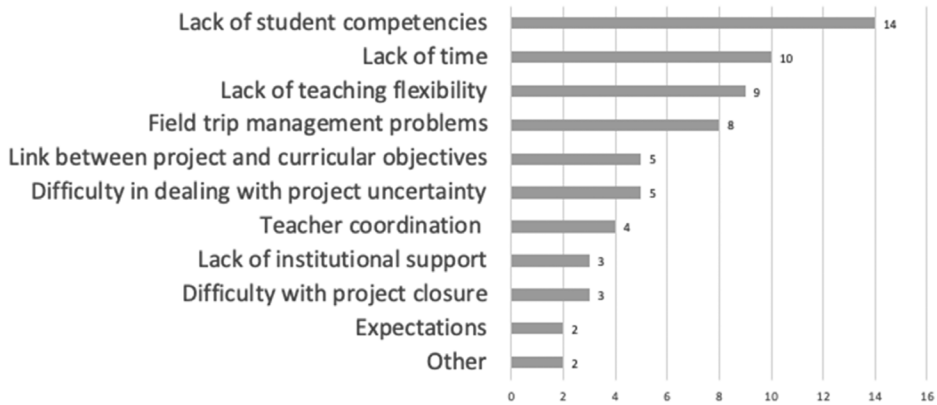(Number of codes present in the documents)

Figure 6. Code counting on "difficulties in the implementation".

What were the main barriers to implementing the project?

After having designed their proposals and reflected on the possibilities of implementation, teachers indicated in the Portácoras and in the final Project-Based Learning showcase that the primary challenges were due to "lack of student competencies," accounting for 21.5% of the total codes. The most frequently cited areas of deficiency were autonomy, scientific and reading competencies, and commitment. The second were: the lack of time (15.4%), with insufficient time for implementation, teacher collaboration, and interdisciplinary planning. Finally, the lack of teaching flexibility (13.8%) also emerges as a significant challenge. This encompasses the difficulty of adapting to educational innovation, the resistance to change, and the lack of adaptability to interdisciplinary subjects and other classroom contexts (Figure 6).

In this context, it is notable that the "lack of student competencies" has become the foremost difficulty, eclipsing the traditionally prevalent block of "insufficient time,". However, in tackling climate change and employing project-based learning methodologies, the focus transitions to students' preparedness to engage with these intricate, interdisciplinary strategies. This transition highlights the essential importance of competences including autonomy, scientific literacy, reading comprehension, and dedication. A teacher noted:

> During the work sessions, a challenge faced with the students was helping them comprehend the breadth of project-based learning, beginning with how to contribute to a goal from three disciplines encompassing various theoretical and practical domains. (Portácora 2)

This remark underscores the urgent necessity to enhance students' competencies for effective engagement in innovative educational approaches, especially those targeting global issues.

Presence of sociopolitical and emotionally responsive perspectives

Do they address aspects of socio-ecological justice in their proposal?

Socio-ecological justice is an absent dimension in 76.5% of the teachers' materials, matching what is found in the literature. The subject matter least addressed by teachers is related to "participation in decision-making spaces" (5.9%), such as municipalities or local authorities, and equal access (5.9%) (Figure 7).

The quotes bellow show two of the few cases that incorporated political discussion on socio-ecological justice:
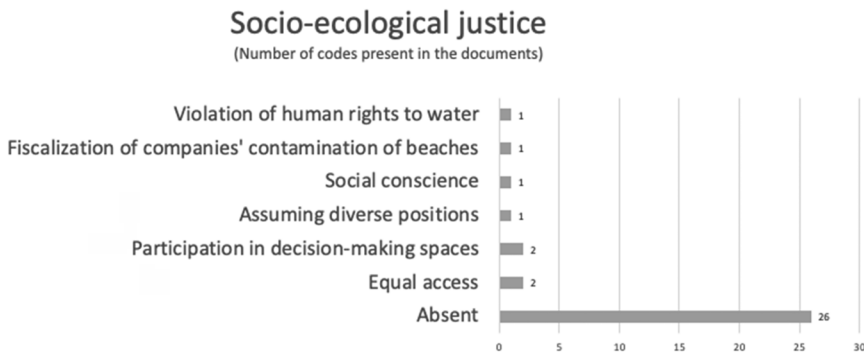
Socio-ecological justice
(Number of codes present in the documents)

Figure 7. Code counting on "addressing socio-ecological justice".

> One variant is to focus the activity on social conflicts that are generating controversy in the political arena. In this way, young people could assume a citizen identity and write an open letter to legislators that can be read. In this way, connections with Citizenship Education and also with the social dimension of argumentation itself are fostered. (Learning script 11)

> Subsequently, at a time to be agreed with the teacher, the course group and their teacher go to the commune square to distribute leaflets among passers-by, giving a brief explanation about the climate risks of the different economic and productive activities of the commune and the way they would affect us. (Learning script 7)

These quotes demonstrate the transforming power of political discussions and socio-ecological justice in classroom climate change education. Student engagement in real-world social challenges, such as writing open letters to legislators, helps them establish a citizen identity. This approach helps students comprehend argumentation as a tool for social change, helping them to critically assess and address social issues.

The second quote emphasizes the importance of community-oriented activities like leaflet distribution in public squares. Civic participation allows students to explain local climate dangers, connecting theoretical knowledge with practical ramifications. By tackling their commune's economic and productive activities, students can improve socio-ecological awareness and foster communal responsibility and agency.

Both instances show the importance of including socio-political factors into climate change education to stress community engagement and systemic transformation. Educators foster a generation of knowledgeable and active citizens who can address socio-ecological justice by encouraging students to participate in political discussions and public debates.

Do they consider socio-emotional aspects?

In 84.8% of teacher materials, the socio-emotional aspects of climate change education were not addressed. Only 9.1% partially addressed it by asking "what emotions does it evoke" and 3% addressed it through personal experiences with the topic (Figure 8).

Socio-emotional factors are crucial for tackling climate change in education, especially with youngsters. Beyond cognitive and scientific skills, empathy, teamwork, and resilience are crucial. These allow kids to manage complicated and often daunting climate-related issues, developing agency and collective responsibility. A teacher offered the following comment after teaching climate change:

> We have a lot to do, and it has been important to be able to share experiences, whether successful or unsuccessful. But we have to heal ourselves, we have to contain ourselves, we have to support each other, and then the children will arrive. We have to be well to be able to generate that knowledge for the students. (Teacher reflection after the poster presentation)

This comment powerfully illustrates the link between educators' socio-emotional well-being and their ability to create meaningful learning experiences for students, especially in complicated and emotionally charged issues like climate change. It emphasizes teachers' mutual support and self-care as a critical step in creating the environment needed to help children through these global difficulties with knowledge and empathy.
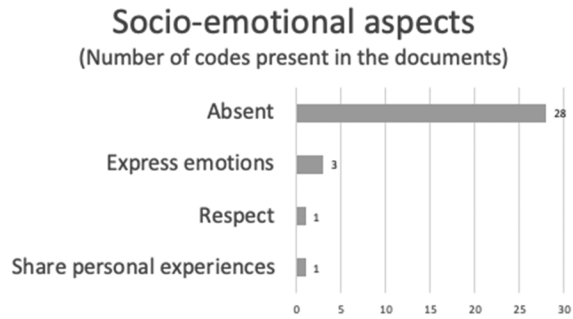
Socio-emotional aspects
(Number of codes present in the documents)

Figure 8. Code counting on "addressing socio-emotional aspects".

Is the perspective of children and young people included in the project?

The perspective of children and youth was absent in 38% of the extracted codes, followed by 'student involvement in the project' with 19%. This included inter-school discussions, involvement of students in planning, evaluation of participation, among others. This was followed by 'Consideration of previous knowledge of students' with 17%, which considers previous knowledge, through the experience of children and adolescents in the subject matter, in the collaborative elaboration of concepts based on previous knowledge and listening to previously stated ideas (Figure 9).

Discussion

The findings of this research are significant because they invite us to discuss and reflect on the principles most mentioned in climate change literature, and therefore examine where we are, and where we need to go. The first relevant finding shows the focus of the participating teachers on natural science content in relation to climate change. This emphasis is important if we consider that in Chile, as in the rest of Latin America, scientific education in the school system is a great challenge and students often fail to acquire the expected scientific knowledge. Therefore, teachers could feel the need to prioritize the conceptual content of natural sciences (OECD, 2023). However, it is essential for teachers to be able to advance toward more complex conceptions and epistemologies of science, in which science is nourished by experts in universities, research centers, experts from the territories, local communities, indigenous people, activists and other groups, who have dedicated themselves to caring for and honoring nature. To achieve this, it is essential for CPD programs to systematically offer learning opportunities in which scientific knowledge is discussed and re-constructed from different perspectives, worldviews and disciplines, thus advancing to a transdisciplinary perspective, which would enable enhanced
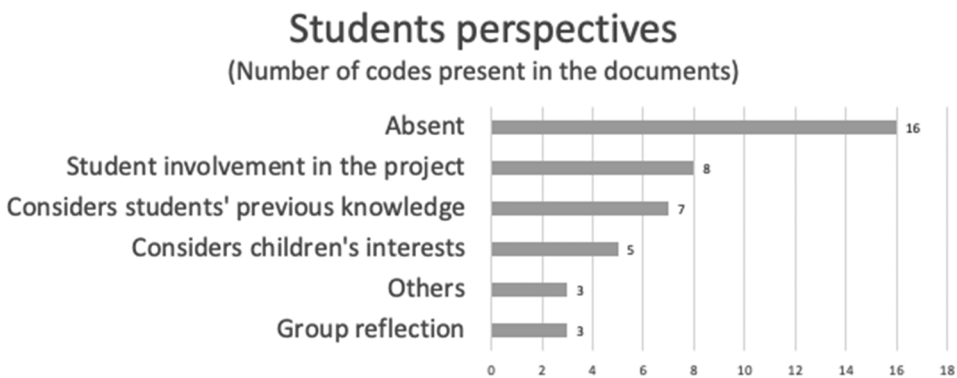
Students perspectives
(Number of codes present in the documents)

Figure 9. Code counting on "considering student's perspectives".

comprehension of complex issues. These learning opportunities should also seek to consider and transform teachers' beliefs about what scientific knowledge is, and what and whose knowledge is necessary to address climate change. The programs analyzed here were designed to include a perspective that values different standpoints, and even teachers valued the active strategies for learning about climate change and how such learning is influenced by how they learned it. Strategies have yet to be found to accompany teachers in epistemological transformation processes, which is a common challenge in CPD programs internationally.

The analysis of teaching materials shows that teachers value ties with the territory and field trips. Indeed, in their lesson plans, most teachers created learning opportunities outside the classroom, with some venturing as far as the schoolyard, which was already a significant step for them. Others designed activities and implemented field trips, representing an excellent starting point to connect with the territories. To enhance these experiences, integrating scientific modeling can be transformative. Teachers can engage students in developing and applying scientific models to explain observed phenomena during these trips, such as modeling the local water cycle or predicting erosion impacts on landscapes. Additionally, students must collect real-world data during these excursions to build and refine their scientific models. This ongoing interaction with models before, during, and after the trips deepens their understanding and fosters critical thinking. Reflective discussions about the models' effectiveness should follow, addressing both scientific accuracy and the emotional resonance of the observed phenomena. This approach requires specific preparation for teachers in scientific modeling to effectively guide students and comprehensively integrate modeling into the learning process. By doing so, field trips transition from simply learning new content to becoming a profound experiential, sensory, and emotionally enriching scientific inquiry that significantly enhances students' engagement and understanding of science in the real world (Marzábal et al., 2024).

How climate change content was taught and learned was a relevant dimension in the reflections of the teachers, who valued learning new strategies to increase their pedagogical tools for teaching climate change in schools. This echoes the literature on CPD for climate change that emphasizes the importance of offering a plurality of diversified pedagogical methodologies to employ in schools (e.g. Chan & Erduran, 2023; Ige & Jita, 2020 Joubert & Kenny, 2018; Philander & Botha, 2021).

In a similar vein, the skills emphasized by teachers in their pedagogical materials produced showed a focus on identifying, describing, knowing, recognizing, comparing and explaining all relevant skills for teaching conceptual knowledge about climate change. There is also an important emphasis on research skills, which can be explained by teachers' concern with teaching conceptual content. Although this group of skills represents a relevant foundation for teaching about climate change, we wonder why teachers do not include more critical skills for their students that promote the solution of real local problems, and commitment to ecological justice. International literature has shown that, critical thinking, justice responsibility and ethics, climate emotions and personal involvement are key to learning and enacting educational innovations on sustainability and climate change (Crease & Singhasaneh, 2023; Lozano et al., 2017).

It seems that even though the programs analyzed here considered local problems and students were invited to identify them and offer viable solutions, the commitment to socio-ecological justice by the teachers was almost absent. This leads us to three reflections. First, it invites us to design CPD programs with a specific focus on socio-ecological justice. Second, it leads us to wonder why this dimension was not present in pedagogical material produced, and third, how to teach for learning and encourage committed intentions and actions in teachers.

On the other hand, the obstacles identified by teachers invite us to reflect on how CPD programs can be more effective. Lack of time is one of the most prominent in the programs analyzed here, and also a constant issue in the review of CPD programs internationally (e.g., Saxena & Chiu, 2022, Körkkö et al., 2022, González-Weil et al., 2014). Although, there are almost no options for resolving the lack of time for implementing a CPD program, it is essential to consider this obstacle in the design and implementation of climate change programs. The territorial experiential approach, and the notion of inhabiting, could contribute to designing learning initiatives that occur from inhabiting specific territories daily, without requiring extra time. This approach could also contribute to the difficulty of teachers' perceptions regarding the lack of resources for field exploration with students. Although experiencing the territory

collaboratively and sensorially, with guidance, is central to learning about climate change, teachers can also learn to design initiatives in which students, can explore their surroundings with their peers and families in everyday life.

Teachers identified families as a crucial stakeholder in Climate Change education; thus, CPD programs should emphasize effective techniques to integrate familial knowledge and encourage parental involvement. It is essential to integrate and exemplify appropriate techniques and methodologies for collaborating with families in varied contexts, such as "funds of knowledge," which facilitates the inclusion of familial insights as a significant contribution to the learning process and offers numerous strategies for fostering, integrating, and engaging families (González et al., 2006; Luna et al., 2023).

Furthermore, some obstacles cannot be addressed by a CPD program regarding the internal management of each school and its response to national guidelines and mandatory requirements. However, identifying and explaining the obstacles that teachers face and discussing them while planning the programs can relieve stress. Learning communities and spaces for collaboration between peers are an excellent strategy for addressing, solving or socializing the challenges of teaching and implementing climate change projects in schools. Collaborative work between communities of teachers has been identified as one of the successful practices of CPD programs (e.g. Damkuviene et al., 2023; Ige & Jita, 2020; Joubert & Kenny, 2018; Philander & Botha, 2021) It is also interesting to note that uncertainty regarding the flexibility necessary for managing field trips were mentioned as obstacles.

Suggestions for future climate change professional development programs

Based on the analysis of the results contained in the international literature, we make the following recommendations for future teacher CPDs on climate change that seem especially relevant to Latin America. It is essential to consider the previous both the personal and professional experience of the teachers and incorporate their knowledge of the local territory, as well as their notions of climate change. International literature has been consistent in pointing out that teachers' prior knowledge is even more relevant in relation to climate change. The knowledge and previous experiences that participating teachers have of their land are key, since they arise from the experience of living and inhabiting in specific locations with climate change problems. This would enable erasing the traditional frontiers between the school and the territory, curricular content, and everyday phenomena, between being a student or a teacher, and being an inhabitant in any particular context. This would provide the opportunity for linking the official general curriculum to everyday life and reflecting on the latter in search of other meanings (Arenas-Martija et al., 2022).

This alludes to the necessity of considering students' perspectives and engagement throughout the entire educational process. We discovered techniques to enhance prior knowledge at the outset of lesson planning; but, to foster involvement and ownership, it is crucial to take into account students' voices and feelings throughout the entire learning process. Implementing active methodology, such as design thinking techniques, to tackle local concerns and enable students to create their own contextually relevant solutions may serve to empower and engage them. Employing design thinking methodologies in CPD programs might facilitate the integration of student perspectives and link climate change to pertinent local concerns.

Along these same lines, the focus on the territories (and field trips) that was valued by the teachers, seems an excellent starting point to advance from field trips to the enjoyment and well-being of community connection experiences. To deepen the solid link with the territories, it is essential for future programs to, on the one hand, highlight the participation of different local actors and experts from each locality to strengthen the different perspectives regarding local problems, and on the other hand, to strengthen the agency of the teachers in their own territory (Yemini et al., 2025). Future climate change programs should consider concrete and systematic instances that promote territorial agency and transformation throughout the program. The literature on agency has been consistent in pointing out that for teachers to commit to societal change, they must be prepared beyond the classroom and with community actors, to advance from a sole focus on education to one of inhabiting this planet (Evans et al., 2017; Burke & Cutter-Mackenzie, 2010).

Forming in proper tools to work with local actors are in the basis for the incorporation of a socio-political perspective. Working together with local organizations, creating spaces to debate about real socio-ecological challenges, gives the opportunity to connect the scientific perspective with aspects related to justice, emotions or local ontologies. The incorporation of multiple perspectives in a horizontal dialogue and working together in possible paths to affront these challenges, creates more comprehensive environments to understand the complex nature of climate change phenomena. Methodologies like project-based learning or design thinking, STEAM approaches or place-based methods can give some lights on how to implement proper learning opportunities connected to student's real-life experiences.

This link to the territory must include the entire diversity of opinions. First, by acknowledging the possible challenges for schools in the dialogue with the indigenous cosmovision, it is crucial for future CPD programs on climate change to systematically include the standpoint of indigenous stakeholders and require teaching materials with this focus. Second, it is important to highlight the fact that the inclusion of the different opinions of children and adolescents in the territories are key for identifying problems collaboratively, and even more essential for creatively seeking solutions (Germein & McGavock, 2024; Henri et al., 2022).

Suggestions for future research

The importance of location in specific territories, listening to and including the voices of local actors, are key elements of a transdisciplinary approach, which should be the core values of future CPD programs. However, the main challenge continues to be not only to integrate this perspective, but to investigate how teachers systematically include this perspective in their own pedagogical materials and classes. This emphasis on the school's surroundings reveals the need for further research in planning, modeling, and implementing field trips with teachers, so they can transfer these practices to their students. This link to the territories and their challenges, on the other hand, calls for further research examining the possibilities and constraints of CPD with ties to indigenous communities, especially in Latin American countries with a significant presence of indigenous populations.

This out-of-school focus, furthermore, evidences the need for teacher leadership and territorial agency in associations that promote social transformation regarding climate change. It seems essential for future research to address the possibilities and challenges of teachers that have an impact inside and outside of schools: could we think of teachers/activists for climate change? What would be the advantages and disadvantages of leadership inside and outside of the school? It is essential to have teachers committed to their schools, education and socioecological justice, to guide their students from the world we have to the world we could have.

A potential synergy may arise from the collaboration of educational academics and educators focused on climate change education. The collaboration between schools and institutions, together with their local communities through participatory research methods, can enhance both CPD opportunities and research quality on the topic (Vaughn & Jacquez, 2020). Utilizing educational research as a means for pedagogical transformation in schools can facilitate suitable opportunities for climate change education, enhance teachers' confidence to spearhead local research initiatives, create environments for the formation of research teams within schools, and foster collaboration in evaluating these experiences.

Conclusions

The teaching materials and their reflections confirm the relevance of designing climate change CPD programs with core principles that consider the six principles discussed in this research: (a) active learning, (b) collaborative learning, (c) place-based learning, (d) culturally relevant teaching, (e) socio ecological justice, and (f) emotions. They also shed light on the possibilities, challenges, and constraints in designing CPD for climate change, which is why, in this final section, we provided suggestions for future research and future CPD programs.

In conclusion, the design of ongoing professional development programs for educators on climate change necessitates a deliberate incorporation of active learning principles, collaborative learning, culturally relevant pedagogy, emotionally responsive methodologies, and a commitment to social justice.

Such programs should be developed to provide educators with both the information and the resources necessary to effectively address climate change in their classrooms. Methods such as experiential learning, inquiry-based projects, co-teaching methods, and peer collaboration workshops can promote significant engagement and skill development.

After revising the teachers' produced materials, two main aspects are key to be considered both for professional development and research: socio-ecological justice and emotional aspects of climate change. Socio-ecological justice should be a primary emphasis, prompting educators to investigate the convergence of environmental and social disparities while enabling students to serve as catalysts for change in their communities. Furthermore, integrating techniques that tackle the emotional aspects of climate change—such as reflective journaling, dialogue circles, and mindfulness exercises—can assist educators and students in constructively processing intricate emotions. Integrating these ideas into professional development enables educators to cultivate resilient, informed, and empathetic generations prepared to confront the problems of climate change with active hope and science-based action.

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Note

1. For further details on the coding process, please refer to the annexes of the article with the detailed matrix of codes and codes extracted from the teaching materials.

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ORCID

Martin Bascopé ⬚ http://orcid.org/0000-0003-1968-9779

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