Learning biodiversity care in everyday life: Teacher education in contrasting biocultural contexts

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Abstract

Earth's biodiversity decline poses critical biocultural challenges, including food sovereignty and climate change adaptation. Teacher education can play a pivotal role in addressing biodiversity care. This study explores how preservice teachers learn about biodiversity care in teacher education programs, focusing on local biocultural contexts to ensure inclusive and equitable quality education pertinent to local communities. Conducted across three diverse Education Faculties in Chile, qualitative methods such as questionnaires, syllabi analysis, and interviews were employed. Findings reveal that preservice teachers primarily acquire biodiversity knowledge through natural sciences courses, albeit with variations across Faculties. The study highlights the importance of situated perception in connecting biodiversity education to the everyday experiences of preservice teachers. It also underscores the ethical and political dimensions of biodiversity education, including participation, interdependence, social commitment, and integration into daily life. Recommendations include fostering collective responsibility, contextualizing teaching methods, incorporating hands-on projects, and modeling responsible biodiversity stewardship in teacher education.

Keywords: biodiversity education, biocultural diversity, learningscapes, SDG 4: Quality education., aesthetics, ethics.

Total words body: 6985

Introduction

Since the second half of the twentieth century, Earth's biodiversity has dramatically declined, along with the ecosystem services it provides (IPBES, 2019). Biodiversity, defined as the variation of life forms, their structures, processes, and interactions across genes, species, and ecosystems, presents a complex scientific concept (Rozzi, 2004; Yli-Panula et al., 2018). While biodiversity concepts are now recognized as essential in science, their inclusion in teacher training programs, particularly for preservice teachers, is just beginning (Bermudez et al., 2022). For example, a literature review that assessed teaching methods in biodiversity education initially found 317 articles. However, only 12 articles directly addressed biodiversity teaching methods and were ultimately selected (Yli-Panula et al., 2018). Prior to their literature review, no comprehensive studies had been conducted on this topic.

Biodiversity loss stems from various causes related to human values and behaviours, including our production and consumption patterns (IPBES, 2019). Usually, these decisions reflect a dominant value system that often excludes indigenous worldviews or local community values (IPBES 2022, Pascual et al. 2023). Consequently, education aimed at addressing these problems must consider the ethical and political dimensions of biodiversity (Rozzi et al., 2023). Neglecting these dimensions calls into question teachers' ability to effectively teach these topics. Education must therefore consider the concept of biocultural diversity (Bridgewater & Rotherham, 2019). This approach is important for achieving inclusive, equitable, and quality education relevant to diverse contexts. Understanding biodiversity implies a biocultural approach for at least two reasons: the experience of diversity is culturally shaped, and scientific inquiry into life and its connections to knowledge is inherently culturally influenced. Thus, biodiversity education and biocultural contexts are intricately linked.

Given the high rates of species extinction and its significant impacts on life, including human well-being (Bongaarts, 2019), and the limited research on biodiversity education in formal contexts (Bermudez et al., 2022; Yli-Panula et al., 2018), we investigated how biodiversity and its care are addressed in preparing future teachers across three distinct ecoregions of Chile. This study is particularly relevant in the Latin American context, characterized by rich biological and cultural diversity, high urban population density, and significant social and economic inequalities (Dobbs et al., 2019). These factors make our findings internationally significant due to similar global inequalities. Moreover, biodiversity is crucial for climate change adaptation and food sovereignty, especially for local and low-income communities dependent on their local ecosystems. Despite its importance, biodiversity is often associated more with specific species and ecosystems than to everyday care (Méndez-Herranz et al., 2023a). Our study aims to bridge this gap by integrating biodiversity learning into the real-life contexts of preservice teachers. By doing so, we consider the multiplying effect that teachers' practices have on students, thereby promoting biodiversity care as critical lifelong learning.

Background

How does teacher education approach biodiversity education and its relation to the biocultural context?

Several studies reveal a disconnect between students' daily experiences and formal education, sacrificing opportunities for meaningful learning (Aston Philander et al., 2011; Bermudez et al., 2022; McCarter & Gavin, 2011). For example, research shows a significant gap in understanding the connection between food chains in natural sciences classes and the food students eat at home, highlighting a disconnect between humans and nature in education and the dominance of a post-industrial Western worldview (Wyner & Blatt, 2019). However, recent findings recognize that environmental learning often occurs in informal, real-world settings alongside our peers, family, and colleagues (Ardoin & Heimlich, 2021). Adopting a biocultural approach to natural science education can help address this disconnect by linking formal learning and everyday experiences to promote meaningful learning.

Western formal education has been critiqued for weakening cultural and linguistic diversity and inadequately incorporating local knowledge (Bermudez et al., 2022; McCarter & Gavin, 2011). Formal education has also been criticized for confining students to classrooms, contributing to their detachment from the natural environment (McCarter & Gavin, 2011). In contrast, studies examining how biodiversity is approached by teachers who belong to indigenous groups and other local communities show how they integrate nature as a living classroom, combining scientific knowledge with Traditional Ecological Knowledge (TEK), challenging the limitations and fragmentation of Western biodiversity conceptualization (Bermudez et al., 2022; Rozzi et al., 2023).

Biocultural diversity is severely threatened by the biocultural homogenization process that jeopardizes both biodiversity and cultural diversity, including languages, traditional knowledge and organizations, among others (Maffi, 2005; Rozzi, 2013). Formal education has been identified as a source of biocultural homogenization (Méndez-Herranz et al., 2023a), evident in the establishment of a hegemonic language within educational systems, the emphasis on modern sciences and mathematics, and the dissemination of Eurocentric perspectives (Debnath, 2020; McCarter & Gavin, 2011; Rozzi, 2012). Integrating TEK into

formal education requires a deep transformation of the educational system because TEK is context-based, community-based, active, experiential, and emphasizes observation, storytelling, and oral transmission of knowledge, among other traits that challenge conventional schooling methods (Aston Philander et al., 2011; Bermudez et al., 2022; McCarter & Gavin, 2011). However, certain aspects of TEK, particularly in medicine, agriculture, and construction, contribute to community resilience and can be more easily incorporated into formal education (McCarter & Gavin, 2011).

Several studies note a disconnect between the curriculum, educational materials, and the local biodiversity in students' daily lives (Castillo-Segura et al., 2019; Celis-Diez et al., 2016; Medina et al., 2020). Science classes sometimes transmit content in a manner that makes it seem isolated from the real world, contributing to both the biocultural homogenization and the alienation of young students from the Earth (Østergaard, 2017). This study delved into the integration of aesthetic experiences in science education, exploring how incorporating the arts, emotions, and developing a deeper bodily awareness can mitigate the feelings of helplessness that arise from the environmental information (Østergaard, 2017). In that sense, natural sciences classes and their teachers can make a decisive difference.

A study conducted by Lindemann-Matthies et al. (2011) in four educational institutions for preservice elementary school teachers showed that biodiversity was primarily addressed in natural sciences modules and focused on scientific aspects. Non-scientific aspects or methodological approaches to biodiversity were rarely included and these courses were optional for non-science teachers. In Brazil, a study found that in-service teachers faced challenges such as a lack of knowledge about local biota, inadequate teaching materials, a curriculum focused on national tests, excessive content, and a preference for general over local biodiversity perspectives (Luvison Araújo & Dos Santos Alitto, 2021, p. 1). Similar issues have been noted in Chile and Latin America, limiting effective environmental education (Condeza-Marmentini & Flores-González, 2019; González-Gaudiano, 2007, Muñoz-Pedreros, 2014).

Integrating biodiversity education with biocultural contexts can bridge formal learning and everyday experiences, making the subject more relatable and understandable for students. This approach also addresses contemporary challenges, such as dealing with non-scientific aspects of biodiversity education and overcoming methodological limitations. Traditional Ecological Knowledge (TEK), often preserved within local communities, can enrich this educational process by imparting practical knowledge and wisdom essential for biodiversity conservation.

How does teacher education in Chile approach biodiversity education?

Chile has legal instruments that support biodiversity integration into education, including the "National Policy of Education for Sustainable Development" (Ministerio de Medio Ambiente, 2009) and the national curriculum. For example, one Transversal Learning Objective in elementary education that directly relates to biodiversity states, "Protect the natural environment and its resources as a context for human development" (Ministerio de Educación, 2023, p. 6). This objective focuses on human wellbeing and natural resource management and not necessarily on the collective concern for all life forms. In general, while the Transversal Learning Objectives outlined in the Chilean curriculum are expected to be taught across subjects and cultivate caring relationships and cohabitation, it largely overlooks

non-human inhabitants such as animals, rivers, or fungi. Additionally, the key learning objectives published after the COVID-19 pandemic in the prioritized national curriculum include contents related to biodiversity but not always to promoting its care. Appendix 1 provides examples of these key learning objectives and their relationship to biodiversity from the authors' perspective.

How does a theoretical 'care' perspective provide insight into biodiversity education in teacher education?

In the current study, we consider a particular concept of care. Saito (2022) proposes that care is the expression of the interdependence of ethics and aesthetics in our everyday relationships with people, places, and objects. This author's concept of aesthetics is broad, encompassing perception and sensitivity in daily life. Both care ethics and aesthetic experiences require attention and connection to open our minds to perceive, understand and actively commit to being present. We embraced this view in a prior study that investigated how aesthetic experiences involving bodies, emotions, and field experiences can provide valuable learning experiences about caring relationships among different species and biocultural ethics (Méndez-Herranz et al., 2023b). A study by Allison (2023) proposed that focusing on Indigenous care ethics offers the opportunity to learn from nondominant groups to foster connection, interdependence, collectivity, and situational problem solving. Understanding care from these perspectives highlights the importance of relationships and interdependence, which is particularly crucial in teacher education. Incorporating these perspectives can address often-overlooked aspects of biodiversity education, such as its ethical dimensions.

This study aims to explore how teacher education approaches biodiversity and its care, recognizing its transformative potential. We also assess the extent to which this learning process is related to the local biocultural context and preservice teachers' everyday experiences.

Materials and methods

This study explored:

1. What preservice elementary school teachers learn about biodiversity and its care during teacher education programs.
2. How these learnings relate to the local biocultural contexts in which they occur.

A cross-sectional design was applied using three cohorts of preservice teachers. Information was gathered by combining qualitative techniques to explore how preservice teachers from three contrasting geographical zones of Chile learnt about biodiversity and its care. We used questionnaires to inquire about biodiversity learning experiences during their studies and analyzed their courses' syllabi for biodiversity-related contents. Additionally, a group of participants volunteered for interviews to discuss their perceptions, values, and emotions associated with learning about biodiversity and its care during teacher education.

Participants

The study focused on third- and fourth-year preservice elementary school teachers to ensure that participants had completed a minimum of two years of formal education at their

universities, following recommendations from prior research (Lindemann-Matthies et al., 2011). Elementary school teachers in Chile are generalists and work with students between 6 and 12 years old. This period of life is essential for developing a lasting connection with nature and the willingness to conserve it (Lindemann-Matthies et al., 2011; Palmberg & Kuru, 2000). In primary school, teachers usually teach four main subject areas: language and communication; mathematics; natural sciences; history, geography, and social sciences. Sometimes, they also teach arts, music, and physical education. The universities that prepare teachers have some autonomy to design curricula and course syllabi. The Chilean Ministry of Education (MINEDUC) provides guidelines, including pedagogical and disciplinary standards (Ministerio de Educación, 2012) and teaching professional standards (Ministerio de Educación, 2021). Nonetheless, faculties of education provide different learning experiences to achieve the teaching professional standards, resulting in a diversity of teacher education programs and courses. Thus, further research is needed to explore how student teachers acquire specific skills or competences (Castillo et al., 2022).

In order to examine how diverse teacher education programs from three contrasting biocultural contexts are linked to biocultural diversity, we used the maximum variation criterion (Patton, 2001). We selected teacher education faculties from the country's northern, central, and southern areas, which will be referred to as the Northern, Central, and Southern Faculty, respectively. A total of 72 preservice teachers participated in this study: 14 from the north, 30 from the center, and 28 from the south. Given the limited size of the faculties of education willing to participate in this study, the number of participants represented about a third of the cohort size. Table 1 provides information about the cohorts of each Faculty.

Table 1. Participants and cohorts of each Faculty

Faculty	Number of students enrolled in the program (2018 -2019)	Number of students who completed the questionnaire (2021)	Percentage of completion
Northern Faculty	2018: 28, 2019: 35 **Total: 63**	14	22.22%
Central Faculty	2018: 46, 2019: 44 **Total: 90**	30	33.33%
Southern Faculty	2018: 39, 2019: 30 **Total: 69**	28	40.58%

The invitation to participate was extended via email to all third- and fourth-year preservice teachers, following the Ethics committee guidelines that approved this study (protocol approval number 201008008). The data was collected in 2021 during the second-year closure of universities in Chile due to the COVID-19 pandemic. The data analysis was completed in 2022. This article was written in 2023. Participants in the study experienced both a social-political crisis in 2019 and a sanitary crisis from 2020-2021 during their studies, with heavier consequences in urban contexts. We believe these unexpected issues diminished the level of participation in this study; therefore, reaching around a third of the study cohort was considered an acceptable number. The researchers had no prior relationship with the study programs or the participants.

The cohort composition varied between institutions. The faculties from the Northern and Southern zones received mainly preservice teachers from nearby towns. In contrast, the

Central Faculty (located in the country's capital) received preservice teachers from the capital and several other nearby towns. Table 2 describes the geographical context of each university and its institutional emphasis.

Table 2. Faculties of Education, characteristics and context.

Institution	N of participants	Territory features	University features	Social context
Northern Faculty	14	The territory is characterized by its extremely arid climate. The annual mean temperature in 2020 was 16.8 °C, and the yearly precipitation was 3.2 mm (INE 2021). This zone is characterized by scarce vegetation; however, at the marine level, it presents rich biodiversity (Weichler et al., 2004). Two of the main economic activities of the zone are copper mining and fisheries. The Northern Faculty is located in the regional capital city.	The education provided by this institution is characterized by a multidisciplinary approach linked to the school system of the northern macro zone and the Andean area. The graduation profile indicates principles of Christian Humanism, emphasizing social responsibility and respect for people's dignity. The teacher education process promotes critical and informed reflection on society and their work and awareness of their essential role as agents of educational, cultural, and social change.	According to the 2017 census, the region has a population of 607,534 inhabitants, with a population density of 4.8 inhabitants per square kilometer. In this region 2.3 % of the population is rural, 11% are migrants, and 14.1% identify as indigenous people (INE 2018).
Central Faculty	30	The faculty is in the city of Santiago, at 33º 26' south and an altitude of approximately 600 meters. The mean annual temperature in 2020 was 15.2°C, and the yearly precipitation was 187.7 mm (INE 2021). Its climate is semi-arid Mediterranean, and its vegetation consists of sclerophyllous scrublands, forests, and *Vachellia caven* steppes (CONAMA 2008). The city of Santiago is the capital of the country and the economic and administrative center.	The educational spirit of this Faculty is characterized by human and social development, emphasizing direct contact with the school reality and the promotion of permanent dialogue and collaboration with local schools. The pedagogical emphases are the development of reflection and research skills.	According to the 2017 census, the region has a population of 7,112,808 inhabitants, with a population density of 461.77 inhabitants per square kilometer. In this region, 3.1 % of the population is rural, 7% are migrants, and 10.1% identify as indigenous people (INE 2018).
Southern Faculty	28	The Faculty is located at 39º 16' south and an altitude of approximately 230 meters. According to a nearby climate station, the mean annual temperature in 2020 was 11.4°C, and the yearly precipitation was 823.7 mm (INE 2021). The zone is characterized by temperate deciduous, evergreen, and mixed forests (CONAMA 2008). Its main economic activities include tourism, agriculture, and forestry. The Southern Faculty is located in a small city.	The pedagogical training on this campus emphasizes training teachers who are experts in the comprehensive development of children and preadolescents, linking academic work with the community's needs. This Faculty contributes to forming committed professionals who identify with the ethical relevance of pedagogical work.	According to the 2017 census, the region has a population of 957,224 inhabitants, with a population density of 30.06 inhabitants per square kilometer. In this region, 32.3 % of the population is rural, 1.1% are migrants, and 34.3% identify as indigenous people (INE 2018).

Data collection

We employed three different qualitative techniques for data collection: questionnaires, interviews and syllabi analysis. The following paragraphs detail each of these.

1. Questionnaire about nature and participant connections with it

This instrument consists of a combination of open-ended and closed questions, with some items adapted from instruments that assess links with nature (Nisbet & Zelenski, 2013). These results were reported in previous studies (Méndez-Herranz et al., 2023a). This questionnaire was sent by email and answered online by the preservice teachers. Each Faculty facilitated this process. We received 78 replies, of which 72 were complete. This article reports the questionnaire responses to the following open-ended questions, which focus on biodiversity education and care.

> A. Do you have courses in your teacher education program in which you discuss or learn about biodiversity? Which courses are they, and what do you learn in them?
>
> B. How does the pedagogy degree in elementary education at your university contribute to local biodiversity conservation, or how could it contribute?

2. Semi-structured interviews

Semi-structured interviews were conducted with a sub-group of participants who answered the questionnaire and voluntarily decided to participate in an interview. During these interviews, we explored themes related to caring for biodiversity in their teacher education program. It is important to mention that this data was collected during the second year of the COVID-19 pandemic, when the universities in Chile were closed. This period was challenging for most preservice teachers, and we believe it diminished their participation in the interviews. Notably, no preservice teachers volunteered from the Northern University, while six individuals volunteered from the Central University and three from the Southern University. The interviews were conducted remotely, averaging two hours in length. The register was audio-recorded and then transcribed. We used pseudonyms to protect the participants' identities. For example, the second student teacher from the Central Faculty was identified as ST2:CF. This format allowed us to reference participants in the results section while maintaining their anonymity.

We explored the following question in detail: How do you learn to care for biodiversity (including humans) in your teacher education program?

We also asked complementary questions about how they learn to teach about caring for biodiversity, how they feel about their relationship with the place they inhabit, and how this affects them as future teachers. All the interview questions are available in Appendix 2.

3. Syllabus analysis

The Faculties of Education involved in this study shared their institutional course syllabi of the courses available to education students. These included both compulsory and optional courses that addressed topics related to biodiversity. These syllabi varied in length and depth across institutions. While they generally provided detailed content and bibliography information, the methodological and assessment orientations were less explicit. We analyzed

all the courses mentioned by the student teachers in the questionnaire. Additionally, we analyzed courses that were not directly mentioned by the participants but that covered biodiversity-related topics and were available for them to enroll in. We examined the courses' contents, methods, evaluations, and bibliography following Research Question 1: What do preservice teachers learn about biodiversity and its teaching?

We analyzed 33 course syllabi: nine from the Northern Faculty, seven from the Central Faculty and 17 from the Southern Faculty (Figure 1).

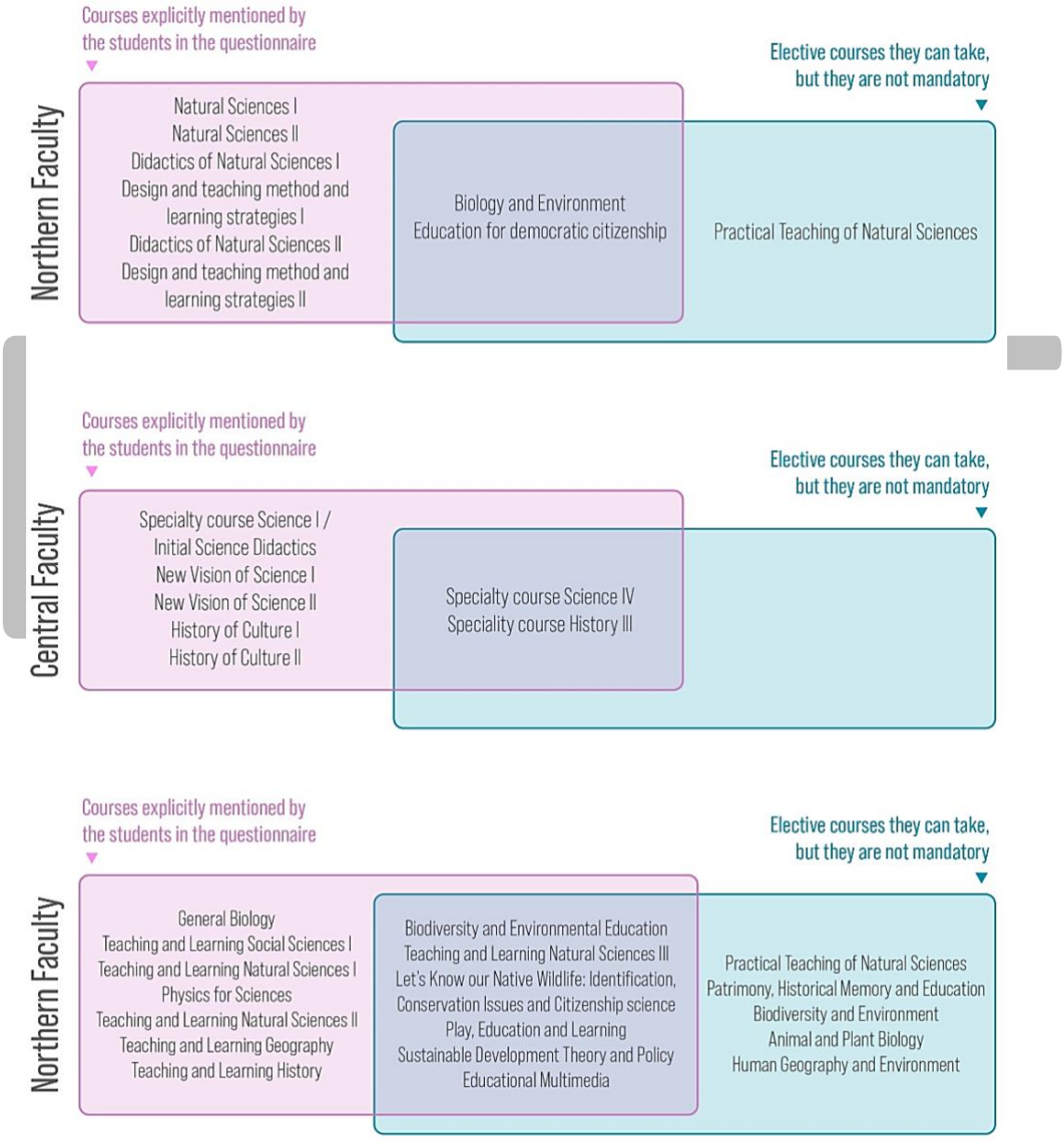

Figure 1. Courses analyzed in each Faculty of Education

* The list of courses on the left side of the red box are the mandatory courses.

Data analysis and integration

The qualitative information obtained from the open-ended questions of the questionnaire, the course syllabi and the transcripts of the semi-structured interviews were first analyzed through descriptive coding. This is recommended for studies involving multiple data types, such as interview transcriptions and document analysis (Saldaña 2009). The process involves iterative and in-depth readings of the texts, followed by the assignment of general codes that describe the emerging themes. We also wrote memos while generating the codes to describe our general impressions. The ATLAS.ti 9 program was used to systematize the coding process. Subsequently, initial narratives were generated from the reiterative readings of the coded information (Newing et al., 2010). These narratives comprised general descriptions of the main results derived from the diverse techniques used for each Faculty. Appendix 3 presents a synthesis of questionnaire response codes regarding how teacher training programs contribute to biodiversity care. It also includes descriptions of the codes and provides select quotes as examples.

Next, to develop a more comprehensive interpretation of this rich and complex phenomenon, we applied methodological triangulation (Cohen et al., 2011) using thematic analysis (Braun & Clarke, 2006; Nowell et al., 2017), specifically, methods triangulation. Thematic analysis helps establish trustworthiness through six phases: 1) familiarizing yourself with your data; 2) generating initial codes; 3) searching for themes; 4) reviewing themes; 5) defining and naming themes; and 6) producing the report (Nowell et al., 2017). We focused on phases 3, 4, 5 and 6 because phases 1 and 2 were completed through descriptive coding. The phases in which we focused involved constant triangulation and discussions about the themes that emerged from the integrated analysis of the information obtained through different techniques. To identify the themes, we used a data-driven inductive approach (Braun & Clarke 2006) that was iterative and flexible. The questions that guided the thematic analysis were:

I. What do preservice teachers learn about biodiversity and its care during their teacher education program?

II. To what extent do these learning processes relate to the biocultural context of each Faculty of Education?

The themes we discovered represent main topics identified in relation to these two questions and are presented as subtitles in the results section (figure 2).

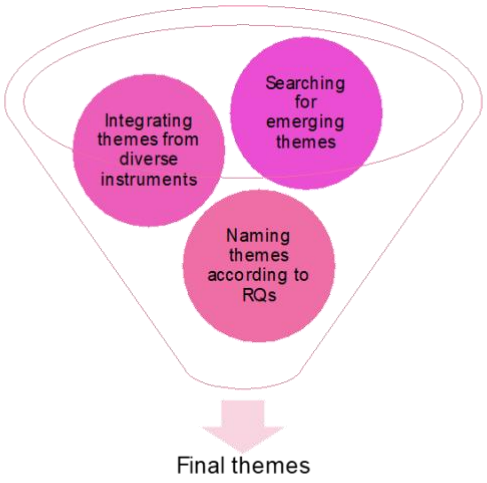

Figure 2: Generating themes from codes and data

Results

In this section, we present our main research findings organized by the two primary research questions, integrating the data collection methods applied.

I. What do preservice teachers learn about biodiversity and its care during their teacher education program?

1.1. Biodiversity is not satisfactorily addressed in all the Faculties of Education

The questionnaire results showed a disparity between students from the Southern Faculty and the other faculties. The majority of participants from the Southern Faculty reported having courses that cover biodiversity, unlike most participants from the other faculties who expressed doubts or felt they did not learn enough about this subject (Table 3), or failed to specify if biodiversity was covered in a specific class. Additionally, most preservice teachers across the three faculties reported that biodiversity is usually included in natural sciences courses (Figure 3).

Table 3. Participants' responses: Have you had courses in your program in which you discussed or learned about biodiversity?

Answer	Northern Faculty (number of participants)	Central Faculty (number of participants)	Southern Faculty (number of participants)
Yes	4	12	21
No	4	7	5
Not enough, not sure	6	11	2

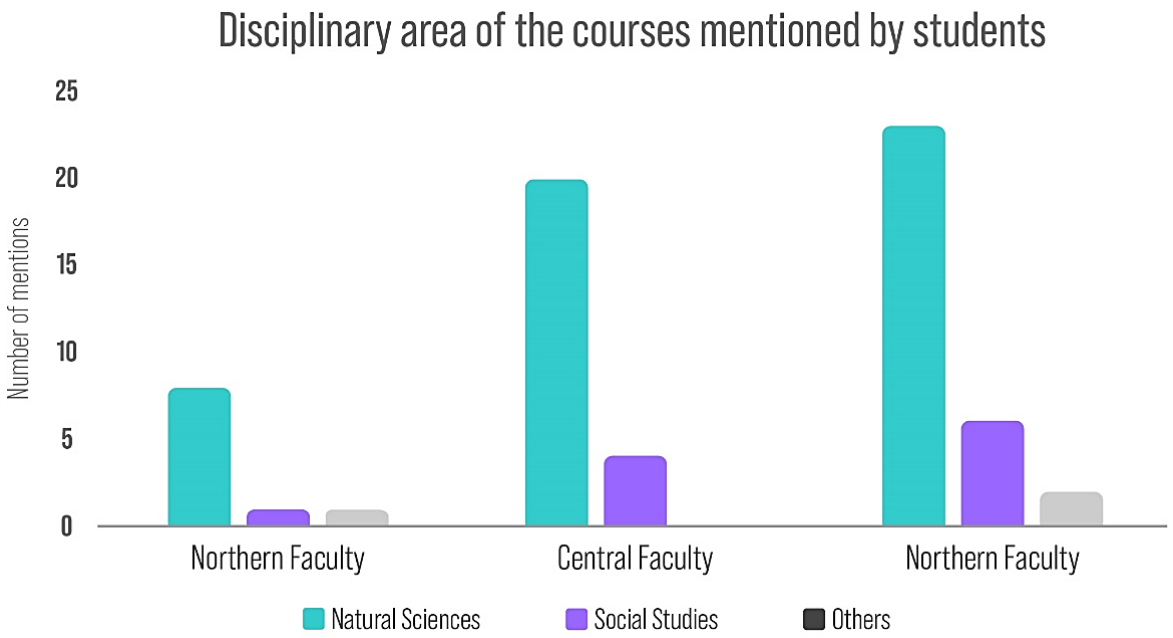

Figure 3: Number of preservice teachers that mentioned disciplinary courses.

1.2. Different perspectives in natural sciences study programs

The syllabi analysis revealed distinct focuses in natural sciences courses across the faculties. The Northern Faculty focuses on social and philosophical aspects of natural sciences, such as the history of science and scientific language. The Central Faculty offers two lines of courses, one that centers on social and philosophical aspects and another that combines disciplinary and pedagogical knowledge. The Southern Faculty focuses on disciplinary knowledge.

In the Northern and Central Faculties, we observed a social emphasis. For example, the introductory natural sciences course at the Northern University states that it "focuses on the review of the foundations with which the sciences are installed in human culture with their own logic, their own products and their own language".

Conversely, the Southern Faculty's introductory General Biology course focuses on disciplinary biological contents without addressing philosophical or epistemological issues or detailing the methodologies or pedagogical objectives of the evaluations. The Southern Faculty possesses strong academic and technical biodiversity knowledge, offering various courses that frequently included field experiences and hands-on methodologies such as citizen science techniques or ethnoecological research. However, interviews revealed that participants from this Faculty criticize the lack of pedagogical tools or support for integrating biodiversity or sustainability topics into everyday classroom activities. They also mentioned the need for additional skills, such as civic or sustainability competencies.

The Central and Southern Faculty courses generally include bibliographies specific to national biodiversity. Some Southern Faculty courses include the Traditional Ecological

Knowledge of the indigenous *Mapuche* people and consider aspects of knowledge transmission such as the relevance of orality and corporality.

Participant interviews from the Central Faculty indicated that their biodiversity training aligns with the national curriculum, progressing from the classification of living beings to trophic webs, and finally to caring for biodiversity and discussing ecology, ecosystems, and interactions. They also mentioned extracurricular classroom activities, such as measuring their ecological footprint or critically evaluating how their decisions affect other people and living beings on the planet. The preservice teachers majoring in Social Studies at the Central Faculty focused on different aspects of biodiversity training. For instance, one highlighted that she learned to "look at things as a whole" (ST2:CF).

1.3. Ethical and political dimensions in learning to care for biodiversity

During the interview analysis, we observed that preservice teachers shared emotional experiences that led to critical reflection about caring for biodiversity. For example, one student expressed disappointment that although she was taught about biodiversity in her natural sciences course, she did not learn about how to care for it. She described a project in which she raised fishes and plants in a plastic column to learn about ecosystems and said, "…I feel that was disrespectful towards living beings because we had fishes and plants in a plastic eco-column, and I do not know, I feel like that project was terrible" (ST3:CF). She continued by emphasizing

> "I feel that I could have learned about the ecosystem without harming anything because besides that, that project, I had those fishes in my house, so I saw how, how the female got pregnant, how the guppies were born, so imagine that it happened two years ago, and it still makes me feel. I cried when the fishes died" (ST3:CF).

Her classmate from the social studies major said that an ethical dilemma arose from that experience. She explained that they talked about it a little in classes, questioning "why the learning had to be based on the utilization or even the suffering of other living beings?" (ST2:CF).

Participants from the Southern Faculty also mentioned uncomfortable learning experiences regarding biodiversity that generated ethical and political debates in the classroom. For example, they recalled experiences during the Native Fauna course in which they went to the forest to install hidden cameras to observe the interactions between domestic pets and the local native fauna. In this way, preservice teachers observed for themselves the severe problems caused by pet abandonment or irresponsible pet care. Subsequently, they discussed the controversies related to a national law regarding the responsible care of family pets.

Additionally, in the questionnaire analysis of responses from participants across the three Faculties regarding how they learned or could learn to conserve local biodiversity in their teacher training, four main aspects emerged: collective actions, contextualization, hands-on projects and the social role of teachers. Examples of responses corresponding to each aspect are provided in Appendix 3, wherein each code is accompanied by its description and relevant quotes.

II. To what extent do these learning processes relate to the biocultural context of each Faculty of Education?

The interviews offered insight into how the teachers responded to the programs based on their experiences and the biocultural context of the learning processes. Contrasting biocultural conditions existed among the three Faculties due to the significant latitudinal gradient that ranges from an arid desert in the north to a temperate forest in the south. The Central Faculty is located in a large, densely populated city within a biodiversity hotspot. The Southern Faculty is located near rural areas with indigenous communities (as shown in Table 2).

In the following section, we present the information collected from the two Faculties that participated in the interviews. This method provided valuable information to understand how the learning processes are related to the biocultural context.

2.1. Central Faculty of Education: Learning to care for biodiversity in urban contexts

During the interviews, preservice teachers from the Central Faculty described the impact of the COVID-19 sanitary restrictions, which included the closure of schools and universities in the capital city, on their teacher education program. They also mentioned the increased relevance of daily life at home under these circumstances. For example, one student explained that she could not learn about biodiversity in a practical setting:

> "Unfortunately, due to the current circumstances at the university, I have not had the opportunity to gain practical experience in a specific school setting. However, the strategies we have learned have been invaluable. Additionally, listening to stories and experiences shared by other teachers has been equally enriching, especially considering the prevailing sanitary conditions." (S4:CF).

Field activities were also cancelled, and as one student explained, "We were going to take a field trip so that we also knew how to lead a field trip on ecology… but we have not been able to do those things" (ST4:CF). Another student stated, "I was going to take that field trip, but they canceled it due to the pandemic" (ST5:CF). Surprisingly, preservice teachers from the Southern Faculty hardly mentioned the pandemic when referring to their formal education experiences. On the other hand, participants from the Central Faculty shared experiences related to biodiversity from a broader perspective, encompassing their daily urban life.

The participants from the Central Faculty narrated their experiences and reflected on the idea that humans are part of biodiversity, a fact often overlooked. This perspective was illustrated in the following student remark, "… talking about the human being, about including it within these... of this care and this biodiversity..." (ST1:CF). Another student reflected on biodiversity care through a social lens. She mentioned learning about the topic during the social uprising ("estallido social") in Chile, a period marked by social manifestations and reflective meetings that occurred at the end of 2019 and demanded dignity for all citizens. Her reflection was not restricted to the protests but also encompassed the spontaneous community activities that emerged during that period. She said these activities were

> "…very positive in perhaps installing this idea of caring for the environment, the collective feeling that it requires commitment and

> participation from all of us. Worrying about water is not just worrying about the community that lives near water, uh... worrying about the exploitative use of land is not just for that community… " (ST2:CF).

Everyday activities were also identified as opportunities to question and learn about biodiversity and interdependence, as expressed in the following quote:

> "…I remember when I was a girl that, I do not know, I only ate strawberries in some months, nowadays [I eat them] almost the whole year. It seems even harmful to me, like... or eating avocado can be super tasty, but it is also harmful" (ST2:CF).

The pedagogical reflections of future teachers involve the idea that learning about biodiversity involves situated perception. For example, one future natural science teacher said that living in the city is not an excuse and that there is biodiversity everywhere: "Because, of course, one can say I live in the city, there are no species, but yes there are" (ST4:CF). She said that even human neighbors are biodiversity, explaining,

> "The tools that I have been able to observe, perceive, and how I would teach, allowed me to learn the importance of starting with our immediate environment. By acknowledging and recognizing our surroundings. While this approach may initially appear biased, it is essential for developing empathy towards others" (ST4:CF).

For example, one student narrated how he discovered biodiversity while walking in the dry hills next to his house during the lockdown:

> "It is the perception, that is, my perception has changed... a lot, a lot, a lot. In fact, sometimes I take my dogs for a walk in a dry hill ("peladero") that is a relatively near home, and I have realized that there are bugs of this size that roam the Earth, and that... now I see it, and seven years ago I would not have seen it and I would not have cared either" (ST1:CF).

Central Faculty participants reflected on how the campus helped them learn about collective caring, providing them with tools to deal with various problems. For example, one student described how she learned to deal with mental health problems:

> "I learned very practical things, especially in the psychological first aid workshop, things that stayed with me to be able to apply. If at any time I see someone in a moment of crisis, I can act and know how to act. It was also a healing experience because they could help me a lot. I was not in good mental health at that moment, and the university helped me a lot, my teachers too" (ST3:CF).

These ways of understanding and thinking reflect the institutional identity of the Central University and the critical and social commitment of their preservice teachers.

2.2. Southern Faculty of Education: Field experiences involving the senses and emotions

During the interviews, most students from the Southern Faculty mentioned field experiences. For example, they explained that in the General Biology course, they participated in field

experiences, such as climbing the Rukapillan Volcano with their teacher, who used to work as a park ranger. The preservice teachers mentioned that, in addition to teaching biological concepts, he also provided practical information about how to behave when visiting national parks, including managing garbage and not bringing pets.

Another example from this Faculty is the Educational Multimedia course, whose syllabus indicates, "Specifically, this course provides theoretical and practical knowledge of design, multimedia communication and information and communication technologies (ICT) in general, in an educational context." A participant said she took the course thinking that she would learn about technologies or social networks, but what she really learned was how to contextualize learning by integrating sensorial experiences, awakening emotions, and reconnecting with her own childhood:

> "The experience that we had there was marvelous, because he made us use all our senses, suddenly he covered our eyes…we put on rubber boots to cross the river, being in the middle of the river and feeling all the sensations, like going back. It made me go back to my childhood" (ST2:SF).

Another student who took the same course also mentioned the sensorial experience and the activity of cleaning up a littered part of the highway between Villarrica and Temuco, "which was practically, already becoming a dump" (ST3:SF). She said the event motivated her to visit the landfill in Pucón, her own town, to collect tires, plastic bottles and other items to transform them into flowerpots. Both participants referred to the inspirational work of the teacher and the impact of the field experiences.

Several preservice teachers from the Southern Faculty described field experiences that deeply affected them with sensory and emotional details. For example, one student mentioned she fell in love with the Native Fauna course. This idea is expressed in the following excerpt:

> "I fell in love even more because there he taught us about how to care for the species, how to identify the species, learn the songs of the birds, so..., that was even more magical to me, like the perception I had changed; as it enriched me more, and now to this day if I go somewhere I start listening to the birds…" (ST1:SF).

The same participant described how she applied this new ability and knowledge in her teaching internship with her own students at a rural school, as illustrated in this quote:

> "I began by listening to the songs of the "tenca" (*Mimus thenca*) and the "fiofío" (*Elaenia albiceps*). Then, while at school, the children started asking me, 'Miss, what bird is that?' I would inform them, and gradually, we initiated the process of identifying various bird songs" (ST1:SF).

Discussion

This study sought to explore what preservice teachers learn about biodiversity education and its care within their teacher education, across three diverse biocultural contexts, and to examine how the learning process was connected to the local context. Questionnaires, syllabi analysis, and interviews were used to gather in-depth qualitative information and method

triangulation was employed to enhance research validity. While our focus was not on making direct comparisons, the study identified differences in biodiversity care across the diverse contexts explored.

The results revealed that biodiversity knowledge was primarily acquired through natural sciences courses, although disparities among faculties were evident. Most preservice teachers from the Northern and Central Faculties felt that biodiversity was not adequately addressed in their study program. Conversely, most students from the Southern Faculty believed that biodiversity was adequately covered in their courses. Across all Faculties, biodiversity education was primarily offered within science-oriented courses, which are often limited to students majoring in this area, consistent with previous research (Lindemann-Matthies et al., 2011). Indeed, the teacher education curriculum of the Northern and Central Faculties focus more deeply on social, philosophical, and pedagogical aspects of natural sciences, while the Southern Faculty concentrates mainly on technical scientific aspects. Nonetheless, we found that the Southern Faculty offers several elective courses related to biodiversity, further enriching the opportunities to learn about the topic.

Field activities play a critical role in shaping perceptions of local biodiversity, prompting participants to reflect on how their personal lives contribute to biodiversity awareness. Ethical and political dimensions arising from such learning experiences, intertwined with emotions, were also highlighted. Vital elements that foster education about biodiversity care include participation, interdependence, social commitment, and integrating learning into daily life. The concept of situated perception notably connects biodiversity education to the everyday experiences of preservice teachers. These results are interpreted in the following section in the context of prior international research.

How the learning process connects with biocultural contexts

The learning processes of preservice teachers are connected with the biocultural context of their respective Faculties, as highlighted in the interviews from the Central and Southern Faculties. The Southern Faculty makes an explicit effort to consider the indigenous local culture in the education of future teachers, alongside the landscape and biodiversity of the region. In contrast, while the Central Faculty addresses sociocultural and political contexts relevant to biodiversity education, it does not emphasize protecting local biodiversity. This is noteworthy because the Central Faculty is situated within a biodiversity hotspot, globally prioritized for protection due to its high richness of endemic species highly threatened by human activity (Arroyo et al. 2006). Moreover, the region is under-represented in the country's protected areas (Pliscoff, 2022), highlighting an urgent need for action.

Participants from the Central Faculty reported learning about biodiversity through deep reflections on the connections between nature and their daily urban activities, such as eating or drinking water. This differs from prior studies that noted difficulties in establishing connections between formal learning and everyday life (Aston Philander et al., 2011; Bermudez et al., 2022; McCarter & Gavin, 2011). The pandemic and the ensuing lockdown during their teacher education training could have contributed to exposing how everyday landscapes or actions influence their learning process (Ardoin & Heimlich, 2021). They understand the profound interconnections among all lifeforms and the need for dialogue and social connections to protect biodiversity, including themselves. This finding connects with previous studies on care in non-dominant groups, highlighting interdependence (Allison,

2023). However, addressing biocultural education in urban contexts through territorial experiences and hands-on activities is a relevant subject that requires further study.

Regarding the learning processes influenced by the course bibliographies, we found that the Central and Southern Faculties included specific books on local biodiversity unlike the natural sciences syllabi of the Northern Faculty. This finding is interesting because other studies have criticized textbooks for young students for their lack of focus on local biodiversity (Castillo-Segura et al., 2019; Celis-Diez et al., 2016; Luvison Araújo & Dos Santos Alitto, 2021). Our analysis showed advances in this regard and the intentional inclusion of local biodiversity books in two of the three Education Faculties. Moreover, some courses in the Southern Faculty considered Mapuche Traditional Ecological Knowledge (TEK) and its pedagogical characteristics, such as oral narratives, as methods of knowledge transmission. This exemplifies how to begin integrating TEK into formal education practices. We interpret this finding as a valuable shift towards including local co-construction and conservation of knowledge, potentially preparing future teachers to adopt practices that promote the conservation of local biocultural diversity (Méndez-Herranz et al., 2023a).

Learning to care

Participants connected learning about biodiversity with feelings like wonder or pain during experimental or field experiences. These examples differ from some literature criticizing abstract science teaching (Østergaard, 2017). Many of the experiences described by participants triggered ethical and political discussions about biodiversity in daily life and national laws. These results connect with the concept of care as the convergence of aesthetics, meaning sensitivity, and ethics (Saito, 2022). This finding is interesting because it differs from other studies indicating that teacher education programs often neglect methodological or non-scientific aspects of biodiversity education, despite acknowledging their importance (Lindemann-Matthies et al., 2011). Conversely, the present study found that some preservice teachers were aware of social and personal facets of biodiversity learning, fostering spaces for political debate and ethical considerations. This pattern was especially notable in the Central Faculty, located in the country's capital, which was a central point for an ongoing political reflection process known as the social uprising ("estallido social").

Interdependence, social commitment, participation, and everyday life learning were frequent topics among preservice teachers from the Central Faculty. These ideas align with the concept of environmental learningscapes, which proposes that learning occurs in diverse settings, with different people, and in everyday life, fostering reflection and the construction of meaning (Ardoin & Heimlich, 2021). Situated perception was an essential element in contextualized biodiversity learning that resonated with students' daily lives. Perception is essential for caring (Saito 2022), and it can be cultivated by spending time observing different environments, as illustrated in the students' narratives. Paying attention to perception is important because, as Marini (2020) suggests, our fundamental relationships with ourselves, others, and the world are based on a perceptual dimension that can be nurtured to enrich our lives. Some participants recognized the importance of paying attention to their surroundings or neighbours as a way to increase empathy and biodiversity care. They also mentioned that certain places or learning experiences can expand their perceptual capacities, revealing living beings they may have previously overlooked. This finding is relevant for achieving inclusive, equitable, quality education pertinent to specific contexts.

Limitations of the study

The main methodological limitation of this study is the lack of interview participation from the Northern Faculty, which limits our understanding of preservice teachers' experiences regarding their questionnaire responses and the syllabi analysis. This hinders our comprehension of program implementation in the Northern Faculty. However, since this study was exploratory and not intended to represent all geographical zones, the results still provide valuable insights into the research question. Moreover, the diverse research techniques and triangulation used allowed us to construct a broad perspective of the study programs, including preservice teachers' perceptions.

Additionally, we did not study why the Faculties of Education have different syllabi offerings and the criteria guiding their decisions, which is another limitation.

Conclusion

This study advances our understanding of what future teachers learn about biodiversity and its care in different biocultural contexts. In the Southern Faculty, we observed advances in integrating TEK into the formal education of preservice teachers. We also noted that participants from the Central Faculty recognized urban spaces as nature, offering deep reflections about how everyday actions affect biodiversity, including humans.

Generally, there is more emphasis on learning about biodiversity than on caring for it, even though participants from the different faculties mentioned that ethical and political issues were addressed in their classes. Given the severe global biodiversity crisis (IPBES, 2019), we must learn different ways to relate to, care for, and value biodiversity from the diverse cultures that inhabit the various ecosystems of the world (IPBES, 2022).

We propose that teacher education programs can help overcome these challenges by integrating the following aspects into syllabi design: 1) developing collective action and commitment to responsibility; 2) contextualizing pedagogical approaches by connecting teaching practices to local biocultural contexts; 3) developing hands-on learning projects that engage preservice teachers and students, such as improving habitat conditions or conducting biodiversity monitoring and; 4) modelling of responsible biodiversity stewardship by teachers, demonstrating awareness of their actions as citizens and neighbours of various species. Teachers are role models for children, and their actions can have a multiplier effect in the community.

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Appendix 1. Key Learning Objectives of Natural Sciences, Primary Education (Ministry of Education, 2023).

Examples of learning objectives related to biodiversity and its care	First grade OA5 "Recognize and compare various plants and animals of our country, considering the observable characteristics, and proposing measures for their care" (p. 6). Second grade OA5: "Observe and identify some native animals that are in danger of extinction, as well as the deterioration of their habitat, proposing measures to protect them" (p. 7). Third grade OA4: "Describe the importance of plants for living beings, humans and the environment (for example: food, breathable air, derived products, ornamentation, medicinal use) proposing and communicating care measures" (p. 9).
Examples of scientific understanding of biodiversity	Second grade OA3: Observe and compare the characteristics of the life cycle stages of different animals (mammals, birds, insects, and amphibians), relating them to their habitat" (p. 7). Third grade OA2: "Observe, record and identify various plants of our country, including autochthonous plants and main crops at the national and regional level" (p. 9). Fourth grade OA3: "Give examples of food chains, identifying the role of producing organisms, consumers and decomposers, in different ecosystems of Chile" (p. 10).
Examples of biodiversity as natural resources that must be managed	Sixth grade OA11: "Classify natural energy resources as non-renewable or renewable and propose measures for the responsible use of energy" (p. 14). OA16: "Describe the characteristics of the Earth's layers (atmosphere, lithosphere, and hydrosphere) that enable the development of life and provide resources for humans and propose measures to protect these layers" (p. 15).

Appendix 2: Interview questions

1. What characteristics do the places you like have? (aesthetic preferences / topophilia)

2. How does the habitat you are currently in influence your pedagogical formation process and vice versa? (relationship between pedagogical formation and environment)

3. How identified and connected do you feel with the place where you live, study, and conduct your teaching internship, and how does it influence your way of being or inhabiting? (identity and belonging)

4. How do you learn to care for, and teach others to care for biodiversity (including human beings) in your pedagogical training process? (care relationships)

5. In your experiences in classes and professional internships, how do you learn to work as a team and promote participation? (participation and collaborative work)

Appendix 3. Examples of questionnaire responses codes about how teacher training program contributes to biodiversity care

Code	Description	Quotes
Collective commitment	Participants recognized collective commitment and collective work as necessary for caring for biodiversity. In that sense, they also mentioned the importance of identifying themselves as part of biodiversity.	"Starting in primary school, it should be built into learning that caring and social commitment is the duty, work and responsibility of everybody, and thanks to the planet we are on, we can develop ourselves and be who we are" (ST1:NF). "The study program for teachers in our university imparts a community spirit that shapes teachers' collective perspectives. This influences our pedagogic and didactic duties and pushes us always to link with the surroundings, a central action to understand ourselves as part of the environment and not above it. Understanding that we are part of something not only creates a sense of belonging but also the commitment for caring with and for the surroundings" (ST1:CF).
Contextualization	Participants identify the importance of connecting and learning about the biodiversity of the local contexts to propose meaningful pedagogical experiences.	"They could teach us the flora that corresponds to the area's climatic conditions, and this way, we could create plans for pedagogical activities with future students to study these species…" (ST4:NF). "It is a tool and a pertinent opportunity to work in context and generate significant learning" (ST2:SF). "Working in collaboration with local biodiversity and knowing it better" (ST5:SF).
Hands-on projects	Participants mentioned the importance of real-world active experiences to learn to care about biodiversity.	"Connecting learning about environmental care with hands-on activities oriented towards teaching practices in action and service…" (ST3:NF). "They could do projects about reforesting places, transplants, among others" (ST4:SF).
Role as teachers	Participants reflect on their crucial role in society and the world, and their responsibility since their actions will be an example for children.	"I definitely feel that teachers are the people who play a key role in creating consciousness among the students for the environment and the conservation of the biodiversity that surrounds them. Because our actions will be an example for the children, it is very relevant that teachers have an objective in their lesson plans to build a sustainable and fraternal locality and country (ST5:NF). "It makes me think about the topic from my role as an educator, contemplating my weaknesses about it and how this can affect the achievement or failure to shape citizens who are aware of nature conservation" (ST5:CF).