Critical scientific and environmental literacies: Exploring opportunities from outdoor education

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I declare that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Gonzalo Guerrero, November 2024

This thesis, excluding the terminal list of references, is 96,116 words in length.

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Abstract

In the global climate crisis, scientific and environmental literacies are crucial for sustainable transformations and climate actions. Research shows that conventional definitions of literacies are often disconnected from global challenges and are controversially supported by neoliberal-capitalist agendas. In Latin America, especially Chile, hegemonic approaches in the curriculum and teacher training shape science educators' perspectives and practices.

This thesis explores opportunities through outdoor education and collaborative research to promote critical approaches for scientific and environmental literacies, based on critical theories and Freirean pedagogies. In doing so, a field trip to El Morado National Park, a glacial cirque impacted by the Alto Maipo environmental conflict, was planned and executed in Chile with 11 participants, including pre-service and in-service teachers, science educators, park rangers, and the author.

The thesis aimed to answer three research questions: (1) How have critical scientific and environmental literacies been understood in the last three decades, and what opportunities exist for their convergence? (2) How does collaboration enhance the expertise of pre-service teachers in outdoor education? (3) To what extent can outdoor education promote a critical approach to scientific and environmental literacies?

A systematic review within this thesis reveals tensions among paradigms of scientific and environmental literacies, noting emerging decolonial approaches and potential convergences of these concepts. The lack of outdoor education opportunities in teacher education presents challenges, with pre-service teachers often relying on self-taught methods. However, after collaborative research, the pre-service teachers in this research demonstrated increased expertise, recognising educational opportunities from visiting El Morado and planning interdisciplinary activities.

Ultimately, the thesis confirms that outdoor education fosters scientific and environmental literacies through conscientisation processes where individuals become critically aware of their relationship with nature and advocate for socio-ecological justice. Thus, outdoor education and collaborative research promote ecological and social justice through informed, action-oriented teaching practices, benefiting students and broader communities.

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Impact statement

This doctoral thesis addresses the need to rethink the concept of literacy in science and environmental education. The research findings demonstrate that traditional literacy visions often alienate individuals by disregarding their specific realities and contexts. Therefore, a general impact of the thesis is about rethinking the importance of incorporating and promoting Latin-American perspectives, epistemological, and theoretical approaches on science and environmental education to foster collaborative ways to address ecological and social issues. This thesis also reveals ideological contradictions in sustainable development goals (SDGs) and proposes new perspectives based on Freirean conscientisation, integrating territorial and contextual knowledge about socio-scientific and socio-environmental contexts.

This research impacts science education by providing a systematic review of the past three decades of critical perspectives on scientific and environmental literacies challenging traditional definitions and advocating for more inclusive and contextualised approaches. Findings support further research in critical and cultural studies, interdisciplinary curriculum development, and recognise outdoor education as essential for promoting conscientisation in science and environmental education. This thesis contributed to the development of a widely used textbook in Chile, now adopted by science teachers nationwide (see Guerrero et al., 2022). The book's impact is evident with over 7,500 downloads from ResearchGate, highlighting its significance. Consequently, this thesis paves the way for new theoretical frameworks and methodologies in various educational fields.

The findings also highlight the role of education in tackling global challenges such as climate change, water scarcity, and biodiversity loss, contributing to more informed and engaged citizens. The integration of scientific and environmental literacies as a collective endeavour can empower local communities, enhance environmental awareness, and promote a contextualised science education approach based on action.

While the primary focus of the research is on educational and societal impacts, there are potential economic and industry implications. A critical understanding of environmental and scientific issues can impact on local research projects to lead to innovations based on contextualised 'sustainable' practices. Educating future generations with a strong emphasis on ecological literacy can help drive industries focused on climate change adaptation and mitigation.

The thesis has the potential to impact cultural understandings and policy-making processes, particularly in the realms of education and environmental management. Through the inclusion of different voices and from a biocentric perspective, the research supports policies that recognise and respect diverse cultural practices and ecological wisdom. This approach can impact the development of educational policies and curriculum reforms that prioritise community engagement, and environmental justice, aligning with broader goals of social and ecological resilience.

This collaborative research project explores the potential of integrating diverse epistemological perspectives and voices to enhance pre-service expertise in outdoor education. This thesis demonstrates that collaboration with park rangers significantly enhanced scientific and environmental literacies of pre-service teachers through a deeper understanding of ecological systems and sustainability principles. The research shows that collaborative approaches can enrich educational experiences and equip teachers to handle the complexities of outdoor education more effectively. Consequently, this thesis has an impact on promoting ecological and social justice through informed, action-oriented and collective teaching practices, ultimately benefiting pre-service teachers and broader communities.

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This thesis is about struggles, dreams and hope for just worlds.

Chapter 1. Introduction and rationale for the study

This thesis is about rethinking the purposes of science education towards social and ecological justice within the global context of climate crisis. In this chapter, I will outline the inspiration and motivation behind my reflections on, and promotion of, critical scientific and environmental literacies. I aim to illustrate how these literacies can open up opportunities through collaborative endeavours. The thesis investigates these opportunities through outdoor education and collaborative, participatory research, drawing on critical theories and Freirean pedagogies.

At the European Science Education Research Association (ESERA) conference in August 2019, I had the opportunity to meet Andri Snær Magnason, one of the invited plenary speakers. Andri was in charge of delivering the opening speech at one of the world's most important conferences on science and environmental education. That year, about a thousand science educators and researchers attended this global event. I was very excited since it was my first time as a teacher-researcher in science education attending this world-famous conference in Bologna, Italy. The magnitude of the event was overwhelming. I never saw before so many people interested in the same field and my expectations about the talks of key speakers were high and Andri's talk did not disappoint me. In fact, it exceeded my expectations, offering insightful perspectives and stimulating in me a deeper and new understanding of the planetary climate crisis.

Andri's inspiring and impactful talk focused on glaciers, time, and water, and how some humans continue to assume that the atmosphere can continually absorb emissions, the ocean can endlessly absorb waste, the soil can constantly renew itself with more fertiliser, and animals and non-human entities can keep surviving as humans colonise more and more spaces. In his ESERA talk, Andri makes echo of his book *Time and Water,* by saying:

> We are living in complex and accelerated times. Changes that previously took thousands of years now happen in one hundred or less. Such speed is mythological and it is affecting all life on Earth, it affects the roots of everything we think, choose, produce, and believe. It affects everyone we know, everyone we love. The changes surpass any of our previous experience and surpass most of the language and metaphors we use to navigate our reality. (Magnason, 2020, p. 7)

His talk and book about glaciers resonated a lot with my conception of time, and my conception of the intertwined perception of past, present and future, my understanding of scientific concepts such as ‘glacial melt’, ‘record heat’, ‘ocean acidification’, ‘climate change’ and particularly on my critical imagination, conceptions of reality and about the impacts and possibilities within global climate crises. As Andri Magnason (2020) presented, climate catastrophe discussions from the discourses of the Intergovernmental Panel on Climate Change (IPCC) are full of scientific concepts and complex statistics:

> 2100 is considered the year that aragonitic sub-saturation in the Arctic is expected to have a significant negative impact on calcium-forming organisms as ocean pH approaches 7.8 compared to RCP 60 scenario outlined in the 2018 United Nations Climate Change Report of 2018. (p. 88)

As we can see in this excerpt, the message might incite fear, awareness, and, ultimately, action. However, for me these are not spontaneous emotions necessarily. We need to know many things in advance to understand what is going on in the world in terms of climate change. For instance, we must have a certain level of comprehension about formal aspects of chemistry such as aragonite, calcium saturation, pH, and atmospheric carbon dioxide. Additionally, we need to know how changes in these can impact our daily lives and the lives of our beloved communities. Ultimately, we need to be conscious of why and how we arrived at this situation and finally, if possible, move towards a deep understanding of who are behind this catastrophe in order to take a stand and act.

For all these reasons, it seems we need to understand science and to be ‘literate’ in terms of the scientific knowledge we need to take action, but also be literate in terms of the environmental and ecological dimensions to be aware of the impact of these crises. These were some of my initial ideas and motivations to start this thesis in 2019. At that time, I had not yet started my PhD and was about to imagine a project related to science education with Prof. Michael Reiss as a potential main supervisor. I was waiting for the outcome of my scholarship application and had begun some preliminary discussions about a potential research topic which was focused on outdoor education and collaborative and participatory research (CPR). In November, when I officially started my PhD at UCL, Andri’s talk continued to resonate in my mind, and my motivation and inspiration to pursue science education became clearer.

However, just four months after this conference, in December 2019, the COVID-19 started to become significant and in January 2020 it was declared a Public Health Emergency of International Concern (PHEIC). In March, the lockdown started in England and my dreams and future expectations about carrying out a PhD were full of uncertainties. The impact of COVID-19 on vulnerable communities, mental health, and disruptions in all aspects of life were difficult to manage, especially while living far away from home and envisioning an incipient idea of a CPR and outdoors project. Some of the questions I asked myself were: how can I approach people to collaborate on my CPR project when they are struggling daily with the impact of COVID-19? Should I adapt my research approach towards a more 'traditional' model? What will the benefits for participants in my research, then? How will I keep participants involved in the project when the future is uncertain? How will I find the motivation to carry out my doctoral research when people are dying day by day and struggling with other issues? I feel grateful to have the constant support from my supervisor, but other than that, I needed help finding academic and emotional support from the university or a network of PhD colleagues doing CPR. I felt lonely, isolated and vulnerable confronting the next stages of my research without a clear picture of what was coming.

Therefore, this thesis and collaborative research project were designed during the early phases of the global COVID-19 pandemic. My fieldwork was carried out during the pandemic, and this introductory chapter is written in the ongoing so-called 'post-COVID' era. I mention this because the pandemic has left us with an emotional crisis that has been strongly felt in schools and in the majority of higher education institutions. The global pandemic has brought severe social, political, and economic disruption, and numerous studies have shown that emerging infectious diseases always have ecological, scientific, and interconnected environment-related issues (McNeely, 2021), to which it seems we have not paid enough attention regarding the role of science education, as also discussed by Andri in his ESERA talk.

Additionally, the pandemic has prompted us to reflect deeply on what we are doing – or not doing – in education, particularly in science education due to its close relationship with health and ecological education. Particularly in the context of health education, Martins (2019) identified attempts to advance this field from within science education, recognising health education as a right and a fundamental element in both individual and collective decision-making processes. This global situation has raised questions about the objectives or *visions* of scientific and environmental literacies. In this context, some authors argued that science education has failed (Dillon & Avraamidou, 2021). Generally speaking, I agree with this claim; however, I also recognise a risky tendency towards reductionism, which can be misunderstood as a process of 'over-educationalising' crises. Such an approach implies a reductionist view that believes education alone can address and resolve all complex social, health, economic, and political crises.

For me, education is part of the solution but not the only one. Education is not to blame for all of society's problems. Although education plays a significant role in shaping individuals and communities, it is just one component of a complex social system. Many societal issues, such as economic inequality, systemic racism, political corruption, and environmental degradation, are influenced by a wide array of factors beyond the scope of education alone. Recognising this potential tension is crucial; blaming education, and specifically science education, for these problems overlooks the root causes and multifaceted nature of these challenges. Economic policies, historical contexts, cultural dynamics, and governance structures all interact to create the societal landscape we navigate. I strongly support the need to reconsider the role of schools within a broader context and integrate other dimensions and elements into the equation due to the complexity of social, political, and cultural phenomena. Education can indeed be a powerful tool for change and transformation, offering individuals the knowledge and skills to understand and address these issues. However, expecting science education to single-handedly resolve deep-seated and systemic problems is both unrealistic and unfair, due to the complexity and interconnectivity of the current global crises. We need to start recognising that we live in a complex world. Thus, this thesis aims to make a contribution from science education to this complex scenario.

Tooze (2022) has suggested that humanity is experiencing a *polycrisis*, where multiple interwoven crises may generate unpredictable mega-threats (Roubini, 2022). One such crisis is the ongoing environmental catastrophe, which worsens daily. This time notably coincides with the COVID-19 pandemic and significant biodiversity loss, marked by the systematic felling of mature trees and clearing of old-growth forests for monoculture farms. The pandemic has underscored the importance of addressing climate change a dramatic example of a socio-scientific issue (Martins et al, 2020).

Additionally, we are witnessing intense global extractivism and what Fraser (2022) terms 'cannibal capitalism'. This environmental degradation has inadvertently set the stage for zoonotic diseases like COVID-19 by increasing human contact with previously isolated wildlife. Both the pandemic and the climate crisis highlight the intertwined vulnerabilities of biodiversity and humanity (Pereira & Viola, 2023). Moreover, the pandemic "has placed scientific expertise at the heart of sociopolitical life, throwing new light on the scientists' fraught navigation of highly contested political spaces" (Weinstein et al., 2023, p. 9). Insights from the pandemic can inform climate action, including reducing fossil fuel use and greenhouse gas emissions, the critical nature of timely responses, advocating for robust and local sustainability practices, recognising the limits of individualism, addressing mistrust in science, and the feasibility of large-scale changes.

To illustrate the connection between COVID-19 and environmental factors, particularly from the Global South perspectives, I consider two examples. First, African deforestation leads to a loss of over four million hectares annually (Pendrill et al., 2022), nearly six times the size of London. In the Democratic Republic of Congo alone, the Congo River basin forests sequester about 8% of the planet's stored carbon and support a diverse range of life, including over 1,000 bird species, more than 400 mammal species, and 10,000 plant species, many of which are endemic. Degrading these habitats increases the risk of zoonotic diseases by disrupting ecological balances and forcing wildlife into closer contact with humans.

Second, in Brazil, deforestation in the Amazon has accelerated, particularly under President Bolsonaro. As of 2020, Brazil reported more than one million hectares of forest loss, a 143% increase from 2012 (Leite-Filho et al., 2021). The country has lost 20% of its rainforest due to deforestation, which critically affects rainfall patterns, agriculture, and access to food and water. Evidence shows that the Amazon Forest's spatiotemporal patterns directly impact global rainfall. As wild species migrate into new habitats due to these changes, they encounter new species and potentially spread infectious diseases (Rohr et al., 2020).

Regarding the climate catastrophe in Latin America, evidence suggests that the poor will be disproportionately affected by related damages (IPCC, 2023; Leichenko & Silva, 2014; Letta et al., 2018). Latin America faces 1,048 socio-environmental conflicts, accounting for 26.6% of global conflicts (Temper et al., 2015). The Global Climate Risk Index 2024 indicates that the poorest countries in the Global South, despite having the lowest industrial pollution levels, are most susceptible to climate catastrophe damage (Eckstein et al., 2021). Strong evidence suggests that initial inequalities put these countries at a disadvantage, making them particularly vulnerable to climate disaster impacts. Furthermore, a World Bank report estimates that the ecological crisis might drive up to 135 million people into poverty by 2030. Consequently, like the COVID-19 pandemic, the climate crisis widens existing global inequalities, undermining efforts to reduce poverty.

In the case of many countries in the Global South, the crises indicated above should also be analysed from decolonial approaches (Mignolo, 2017), understanding that current political and economic models derived or are consequences of historical colonial extractivist mechanisms. We should not forget that the south of our beloved Abya Yala (the original name of America prior to European colonisation and a term used by millions of indigenous peoples of the American continent) is experiencing the consequences of the climate crisis that transgresses the vast majority of dimensions of life, to mention a few impacts: environmental and food systemic crisis, climatic migrations (mainly affecting women), loss of biodiversity, conflicts over access to water and ocean acidification, land and forest degradation (Svampa, 2019).

In Chile, hegemonic extractivist mechanisms have intensified in recent decades due to processes of ‘neoliberalisation of nature’. This term refers to the application of market-based principles and economic policies to the management and commodification of ‘natural resources’ and ecosystems, often prioritising profit over environmental and social concerns (Villavicencio, 2021). This shift has exacerbated environmental degradation and social inequalities, undermining ‘sustainable development’ and community well-being. In Chile alone, there are 131 ongoing conflicts (INDH, 2024), with 85% violating human rights to reside in pollution-free areas, 44% impeding the right to physical and mental health, 44% infringing upon rights to access water, and 31% encroaching on rights to biodiversity (INDH, 2024). Moreover, the Chilean National Institute of Human Rights in Chile reports more than 125 zones of socio-environmental conflicts, including the so-called ‘zones of sacrifice’, which have devastated impacts on natural ecosystems and indigenous groups (INDH, 2024) – communities who are determined to fight for the rights of Nature and ownership of their ancestral lands. The term ‘sacrifice zones’ is applied to geographic areas that have been permanently impaired by environmental damage or economic disinvestment (Lerner, 2010; Scott & Smith, 2017). These zones/territories have been “sacrificed” in the name of ‘progress’, economic growth, development, and energy independence (Bolados & Sánchez, 2017) and are considered a “long-running strategy for the strengthening of neoliberal economic development” (Valenzuela-Fuentes, 2021, p. 2). These extractivist processes not only bring with them the depredation of natural ‘resources’ in our region but also processes of undertaking onto- and epistemic genocide. For instance, the dualism or false dichotomy between human beings and Nature also determines our conception of science or environment (and natural reality), which has been built mainly under the Western gaze of the Global North without integrating the plurality and diversity of knowledge present on this side of the world. The colonisation process suppressed the idea of the human being as part of nature, generating a duality between knowledge and rites, the affective and the productive (Vivas, 2022). The possibility of incorporating ancestral knowledge, and rescuing original ways of (with) living, can contribute to decolonising our Andean territories, allowing the generation of ways of living that are more in tune with our territories. Therefore, it is necessary and imperative to question and rethink the meaning of sustainability and its articulation with *visions* of scientific and environmental literacy in our region.

Arguably, scientific literacy today is synonymous with science education (Queiruga-Dios et al., 2020). For many educational policymakers, researchers in science education, and science educators, scientific literacy is a fundamental factor in the development of individuals and communities, and it might be even more relevant in times of planetary crises. However, typically the discourses that address conceptualisations of scientific literacy are closely related to paradigms and ideologies. For this last reason, we should question: what are we talking about when we talk about scientific literacy? What are necessary visions of scientific literacy in a time of global climate catastrophe? What is the connection between science and environmental literacies? In light of (neo)extractivist processes and climate crisis, what is the approach of scientific and environmental literacies needed in Latin America and Chile?

According to Hodson (2010), a scientifically literate person is one who learns, acquires, and develops theoretical-conceptual knowledge about science; is one who manages to learn about science, developing an understanding of nature and its methods; is one who develops an 'awareness' of the complex relationships between science, technology and society. However, in addition, a scientifically literate person is someone who manages to get involved from experience in scientific research and problem-solving. Following international guidelines, articulated with the so-called *visions* of scientific literacy by Roberts (2007), many curricula and educational policies worldwide have tried to imitate or follow hegemonic agendas promoted from the Global North. As a matter of fact, during the last 40 years, 70% of the institutions that produce knowledge related to scientific literacy are from North America, with very few representatives from other latitudes of the world (Li & Guo, 2021). These epistemic constructs have permeated Latin America's curricula and educational, political hypotheses – in a normally top-down logic – regarding what should or should not be taught in the science classroom (Weinstein et al., 2023). These decisions also continue to favour specific approaches in disciplines such as 'experimental' or 'applied' sciences, which normally address narrow social, cultural, and environmental dimensions through science education.

From reviewing the literature, it seems to be a set of hegemonic visions of scientific literacy which also deeply permeate the curriculum – in some cases from neoliberal rationality – and, therefore, the values promoted are expressed from an individual responsibility that does not allow questioning structural elements or articulating scientific knowledge with socio-political, economic, environmental, ecological or social dimensions (Norambuena et al., 2023; Guerrero & Torres-Olave, 2022). Added to this, science study programs in various countries of the region – with some recent exceptions such as Argentina and Brazil – do not consider holistically, nor at all educational levels, the focus of the current global emergency and crisis (Salinas et al., 2022). Based on the above, we must question what we understand by scientific literacy in the Latin American context, in the so-called global and territorial south.

When analysing the visions of scientific literacy in Latin America, we can observe that there is a transition in the levels of science knowledge, replicating what scientists do from a technical vision in the classroom and applying said knowledge in everyday situations, but generally without actually acting or promote a socio-community sense of science (Guerrero & Torres-Olave, 2022). In short, scientific activity is presented in disconnection from science's human and political dimensions and far from the collective. The traditional visions of scientific literacy do not question the place of the human being in Nature nor the complex interactions that occur between people. Although the climate crisis is addressed in some cases (Salinas et al., 2023), it is done superficially, from individual approaches and decontextualised to territorial problems or socio-environmental conflicts close to the students' territories and contexts.

In Chile, the work of Pérez et al. (2024) has critically examined the normative and curricular documents that shape initial teacher training in science education. Their analysis is structured around six key categories: (1) scientific literacy, (2) science for citizenship, (3) science education, (4) teacher education and standards, (5) teaching and learning processes, and (6) epistemology and didactics. Through this analysis the authors highlight substantial improvements in the way curricula address historical deficiencies in training science teachers (Cofré et al., 2010). This approach signals a shift towards a model of contextual scientific culture (Gómez, 2012) and contextualised scientific literacies (Valladares, 2021, 2022), moving away from traditional scientific paradigms. These perspectives underscore the importance of integrating science with various facets of social reality, particularly through sociocultural contexts.

Nevertheless, this model falls short of fully meeting Chile's specific needs. It lacks attention to regional particularities and does little to adopt the promotion of action, collaboration and a mindset which can connect science with broader socio-political dimensions among science teachers (Pérez et al., 2024). Moreover, it is essential to acknowledge that while some concepts draw on international ideas, the presence of prevailing epistemological tendencies, such as anthropocentrism and determinism, may obstruct the aim of science teachers to advocate sustainability, especially in the context of Latin America and Chile. Consequently, it is crucial to integrate epistemological and *didactic* approaches so that they align more closely with the development of the 'epistemologies of the South' (de Sousa Santos, 2018) to enhance the relevance and contextualisation of science education in Chile.

As various scholars in science education point out, it is time to rethink what is taught in schools and how future scientists and all citizens are trained (Bayram-Jacobs et al., 2022; Reis, 2020). Education must urgently be redesigned to address contemporary societal challenges: "Unless we rethink what it means to be science and environmental literate, science education will continue to fail our current students and future governments" (Dillon & Avraamidou, 2021, para. 9).

In this scenario, it is urgent to consider the role of education in promoting values of responsibility and commitment, as well as a feeling of hope and resilience in tough times in Latin America and Chile. Challenges for teachers and those who design curricular plans and programs are to find a way to equip, inform and empower citizens for active and committed participation. To support them in this search, science education and, in particular, scientific literacies acquire a key role in promoting socio-scientific competencies towards a sustainable transformation with a focus on eco-justice.

Critical scientific and environmental literacies should promote educational processes to articulate political, environmental, health and emotional literacies to achieve this change. Notwithstanding, this critical approach to literacy in Latin America must be territorial (place-based), situated and contextualised, considering a model of scientific awareness that promotes social and environmental justice to educate people who question the political processes and scientific and environmental issues. Students, together with their teachers, must be not only aware of the scientific contents or concepts but also be willing to address the climate crisis and other socio-scientific and environmental issues from the intersectionality of those who inhabit our continent, considering, for example, gender, racial identities, ethnicity, class and age, among others.

1.1 General rationale

This thesis is written under the assumption that climate catastrophe is one of the greatest threats to ecosystems and the associated understanding that we are experiencing one of the biggest humanitarian crises in recent decades. Climate change impacts and risks are becoming increasingly complex and more challenging to manage. This thesis, then, is an invitation to rethink the relevance of acting today in the face of one of the most significant challenges we face as humanity – an invitation to remember the importance of protecting and defending Mother Earth. I believe that addressing the climate crisis in science and environmental education is an opportunity to promote critical awareness and conscientisation processes through education.

Promoting climate and ecological justice should be imperative in science teaching and environmental education curricula. Climate justice should be a principle that cultivates and encourages visions of critical scientific and environmental literacy in a fair, equal and inclusive manner. Thus, a process of scientific, ecological and social awareness. Incorporating a political perspective into the climate change education discussion can help to promote social and environmental justice (Schlosberg & Collins, 2014). Protecting the planet now and today is a way to safeguard the future for future generations.

I started writing my thesis when COP27 was taking place in Sharm El-Sheikh, Egypt, in November 2022. The context in which COP29 is being developed is terrifying. The IPCC, in its last 2023 report, warns us that human-induced climate change has already caused widespread adverse impacts and related losses and damages to nature and people beyond natural climate variability (IPCC, 2023). This situation includes more frequent and intense extreme weather events. Some development and adaptation efforts have reduced vulnerability. However, across sectors and regions, the most vulnerable people and systems are observed to be disproportionately affected. The rise in weather and climate extremes has led to some irreversible impacts as natural and human systems are pushed beyond their ability to adapt. Climate change has adversely affected the physical health of people globally and the mental health of people in the assessed regions (IPCC, 2023). Climate change impacts on health are mediated through natural and human systems, including economic and social conditions and disruptions. Extreme heat events have resulted in human mortality and morbidity in all areas. Climate catastrophe contributes to humanitarian crises where climate hazards interact with high vulnerability. Global warming, reaching 1.5°C in the near term, would cause unavoidable increases in multiple climate hazards and risks to ecosystems and humans. Climate change will increasingly pressure food production and access, especially in vulnerable regions, undermining food security and nutrition (Svampa, 2019). Increases in frequency, intensity and severity of droughts, floods and heatwaves, and continued sea level rise will increase risks to food security in vulnerable regions from moderate to high between 1.5°C and 2°C global warming level, with no or low levels of adaptation (IPCC, 2018).

Particularly in Latin America, the IPCC highlights severe health risks resulting from escalating epidemics and threats to water security, particularly those linked to vector-borne diseases (IPCC, 2023). Additionally, coral reef ecosystems are experiencing significant degradation due to coral bleaching. There are also considerable risks to food security arising from more frequent and extreme droughts. Furthermore, life and infrastructure are increasingly endangered by floods, landslides, sea-level rise, storm surges, and coastal erosion. These challenges underscore the urgent need for comprehensive and adaptive response strategies across the region.

In Latin America and Chile, the dynamics of resource extraction to feed the global industrialised economies have solidified our continent's role as a producer of raw materials (Gudynas, 2018; Lander, 2014). This process has reached an extraction level of 10 tons per person per year (Martínez-Alier & O'Connor, 1996), with the region exporting most of these materials. The overexploitation of raw materials and the accumulation of waste have severely worsened the environmental situation, resulting in a significant loss of biodiversity and natural habitats, excessive use of fertilisers, and water and air pollution (Acosta & Machado, 2012). In this context, socio-environmental conflicts have intensified, which governments often respond to with strong repression and criminalisation (Svampa, 2019). Ultimately, these challenges underscore the urgent need for ecological and sustainable practices and policies that balance economic development with environmental protection and social justice. I strongly agree that science and environmental education play a crucial role in this effort, fostering a deeper understanding of ecological issues and promoting innovative solutions. By prioritising scientific research and comprehensive environmental education, we can empower communities to actively engage to take decisions and actions, ensuring a healthier and more equitable future for our region and particular realities.

1.2 Personal rationale

The global environmental crisis and the COVID-19 pandemic profoundly impacted my personal process as a teacher and science educator. During the lockdown period, when I was living in Cambridge, I had the opportunity to reflect on some 'scientific' discourses around the global pandemic propagated from news and social media. I deepened my ideas about this historical period regarding (un)balance with nature. The pandemic came to show us how the forces of nature are put into tension when human forces leave harmony aside due to over-exploitation and excesses (Wark, 2016).

I firmly believe that our strained relationship with nature has precipitated the current climate crisis. This situation highlights that different sectors of society bear varying degrees of responsibility, with some groups being more culpable than others. It is evident that the world's most vulnerable populations – including those in the Global South (e.g., Svampa, 2019) and the marginalised in 'developed' countries – are likely to continue suffering disproportionate harms. This inequity suggests that more advantaged individuals are engaging in a form of *necropolitics*, essentially making life-and-death decisions (Mbembe, 2019). In the context of the climate crisis, for example, individuals and other living entities in less 'advantaged' situations – often those with lower socioeconomic statuses – bear the brunt of the devastation, despite their minimal contributions to greenhouse gas emissions (Huber, 2022; Turchin, 2023). The diversity and complexity of these issues make it challenging to identify a single underlying cause. However, extensive literature suggests that greed, particularly among those with substantial capital, is a major driver of many global and local challenges (Roubini, 2022).

As a physics and biophysics teacher, I remember my perspectives, *visions* and paradigms of science that I taught in Chilean schools and universities. I am still reflecting on the type of science that I taught for eight years. Some questions and thoughts during the pandemic were: Did I contribute in some way to the training of my students to be able to critically understand the global pandemic and the connection with the various dimensions of life? As a science educator, did I anticipate the importance of science education to confront this global crisis? The answer for these questions is perhaps 'not enough'. Indeed, most of the science that I taught both at the secondary level and at the university level in Chile was mainly based on a content-based, normative, instrumental, uncritical, a-historical, politically, and ideologically neutral science education. However, I do not blame myself since Chilean school science education has traditionally provided few or no spaces to reflect about our own political-pedagogical position. Rarely, science education in Chile is considered as a political activity, to seek transformation or to reflect on reality consciously and critically. This apolitical science education might be explained by the heritage of the civil-military dictatorship (1973-1990) (Torres-Olave & Dillon, 2022).

The pandemic opened and deepened personal questions for the rationale in this thesis such as what is the role of science education and specifically what is the role of scientific literacy in global crises? How are we connecting science education with political, cultural, ecological, economical, ethical and health dimensions? And in the light of inequalities seen during the pandemic, what kind of scientific and environmental literacies do we need to affront the forthcoming climate catastrophe and future crises in Chile? I must recognise how the pandemic evidenced and tensioned even more the meaning and role of science education in time of planetary crisis. The pandemic has brought to the surface persisting structural inequalities that demand new ways of being in the world that centres on 'affect' instead of on 'success'. The above context reframed in depth my initial ideas about this concept and the necessity of investigate more about the complexity and polysemic meaning of scientific and environmental literacy, specifically, in different contexts other than Global North.

I have been reflecting on how my motivation, spurred by Andri's talk and after starting my first year in the PhD, increased because of the COVID-19 pandemic. Now, I could assume that the relevance of scientific literacies is more important than ever. So far, the deadly pandemic makes me reflect on how human-induced climate change, capitalism, and extractivism are challenging the interconnected human-nature relationship. Therefore, from a science education perspective, it is imperative to question this brutal capitalism which seems to overlook the long-term impact of ecocides and the extractivist connection (Fraser, 2022). Science education should be aware of the impact of this crisis and prepare students, teachers, science educators, and researchers to manage the transition to rethink the focus of scientific and environmental literacies, with a focus on eco-justice as a science education imperative (Weinstein et al., 2023).

Furthermore, integrating collaboration into this framework is crucial. My thesis specifically examines the training of pre-service teachers in outdoor education, with the goal of enhancing their expertise. Through collaborative projects, these pre-service teachers can gain a deeper understanding of ecological concepts and pedagogical strategies that are specifically tailored to the unique challenges and opportunities presented by outdoor environments. Moreover, such collaboration fosters a community of practice that facilitates the sharing of ideas, strategies, and reflections. This is essential for professional growth and the effective incorporation of eco-justice principles into educational practices.

Besides, science curricula should be collectively reoriented towards a deep focus on politics, environment, and health perspectives as advocated by Zeyer and Dillon (2019) or situating science education within a framework of social justice, as argued by Reiss (2003) and Weinstein et al. (2023). These adjustments underscore the necessity of integrating collaborative methodologies to cultivate a comprehensive and responsive educational approach in the face of global environmental challenges.

We should rethink the complex systems and socio-political contexts in which people learn and practice science, conceptualising these processes through the lenses of social and environmental justice. This climate catastrophe also offers significant insights into addressing the global climate crisis, given the many similarities between the COVID-19 pandemic and the anticipated environmental crisis among others. The pandemic has highlighted both ecological crises and global inequalities, emphasising the importance of addressing these issues in science classrooms.

Especially, the coronavirus disease uncovered the inequalities between the Global North and Global South regarding social and environmental justice and, therefore, might offer essential lessons for the upcoming global climate crisis. Global emergencies are not new, but our ability to understand, prevent, and manage them is now greater than ever before. For instance, making sense of what is happening requires an understanding of several scientific ideas, including viruses, transmission, incubation, and vaccination. This situation highlights the critical role of science and environmental education in addressing global challenges. By fostering a deeper understanding of these scientific principles and their implications, we can better prepare for and mitigate the impacts of future crises. Emphasising science and environmental education will empower individuals and communities to engage in informed decision-making and proactive measures, ultimately contributing to a more resilient and equitable society.

1.3 Research aim

This thesis aims to examine the development and potential integration of critical scientific and environmental literacies within science education by exploring opportunities to promote these literacies collaboratively through outdoor education.

1.4 Research Questions

1. How have critical scientific and environmental literacies been understood in the last three decades, and what are the opportunities for a potential convergence between these concepts?
2. How does collaboration enhance the expertise of pre-service teachers in outdoor education?
3. To what extent can a critical scientific and environmental literacy approach be promoted through outdoor science activities?

In this thesis, I conceptualise the term "scientific and environmental literacies" to advocate for a transformative, action-oriented approach to these concepts. For me, this term represents a critical perspective in science and environmental education, emphasising the necessity of addressing the climate crisis and ecological issues through a contextualised, broader, interdisciplinary understanding of these fields. In the research questions, this term seeks to integrate scientific literacy with historical, socio-political, relational-existential, economic, and environmental dimensions, offering a broader conceptualisation of the concept 'literacy', incorporating critical, social, ethical, and cultural dimensions for dialogic emancipation and socio-ecological justice, highlighting the role of activism, collaboration and collective action. Similarly, I extend environmental literacies beyond basic awareness to include a deeper and contextualised understanding of the interrelationships and interdependence between humans and nature, aiming for social and environmental justice and challenging traditional, neoliberal approaches that focus solely on economic growth and technological advancement. Central to this perspective is the emphasis on allowing individuals to evaluate and engage with science as a collective endeavour, advocating instead for a more holistic understanding that recognises the interrelationships between humans and nature. This vision is oriented towards praxis, emphasising not just theoretical understanding but also active engagement and the transformation of social realities.

1.5 Overview of the literature review and positioning framework

Several countries have explored the convergence of scientific and environmental literacies with the aim of fostering more holistic and critical educational approaches. In the United States, for example, research has focused on integrating environmental issues into science curricula through socio-scientific controversies such as climate change and sustainability, helping students critically assess the scientific and environmental dimensions of global challenges (Zeidler & Nichols, 2009). Similarly, in Canada, outdoor education has been used as a tool to merge environmental literacy with scientific inquiry, allowing students to experience ecological concepts firsthand while developing critical thinking skills about human-environment interactions (Fazio & Karrow, 2013). In some European countries, such as Sweden and Finland, the convergence of scientific and environmental literacies has been promoted through education for sustainable development (ESD), encouraging students to think critically about the impact of scientific advancements on the environment and society (Jickling & Wals, 2008; Öhman, 2008).

Moreover, as Wals et al. (2014) argue, the growing complexity of sustainability challenges requires the convergence of environmental education (EE) and science education (SE). The traditional focus of SE on knowledge and skills, and of EE on values and behaviour, must evolve into a more integrated approach that addresses socio-ecological issues collaboratively. Citizen science and sustainability concerns can catalyse much-needed synergy between environmental education and science education by blending these literacies through initiatives that engage the public in scientific inquiry and foster a deeper connection with local environments (Wals et al., 2014).

In the Global South, particularly in Brazil and countries in Africa, the convergence of scientific and environmental literacies has also been explored in ways that address local socio-environmental challenges. In Brazil, environmental education not only integrates scientific literacy with local ecological knowledge, empowering communities to address environmental issues like deforestation in the Amazon, but has also evolved into what is known as ‘transformative’ or ‘critical environmental education’. These approaches, which gained prominence after the 1980s, emphasise social change and community empowerment, particularly in tackling environmental crises through a more critical lens, aiming to reshape societal values and practices in line with sustainability goals (Thiemann et al., 2014). In South Africa, interdisciplinary approaches have merged environmental and scientific education to address critical issues such as water scarcity and biodiversity conservation. These approaches encourage students to apply scientific knowledge to real-world environmental problems, enhancing their critical thinking and problem-solving abilities (Lotz-Sisitka, 2010). Additionally, citizen science projects across Africa have enabled communities to monitor environmental changes, linking scientific inquiry with local action to address sustainability challenges (Danielsen et al., 2014). These examples highlight how the convergence of these literacies in the Global South can empower communities to engage with both local and global environmental issues.

Nevertheless, while the literature offers valuable insights into answering my research questions in various international arenas, these issues remain largely unexplored within the Chilean context. Studies from other countries have addressed how critical scientific and environmental literacies can converge and how outdoor education can enhance pre-service teachers' expertise, but there is a lack of research in Chile regarding how local socio-political, socio-environmental conflicts, and historical educational factors influence the integration of these literacies. Additionally, the role of outdoor education in fostering critical approaches has yet to be fully examined in Chile. Therefore, my study aims to fill this gap by exploring these themes within the distinctive Chilean context.

1.5.1 Scientific and environmental literacies

Scientific literacy is a broad concept embracing many historical and educational themes that have shifted over time; it is usually established as an analogy or metaphor between basic literacy and as part of an international extension movement of scientific and technological education (Bybee, 2015; Laugksch, 2000). Sjöström and Eilks (2018) consider a new focus of scientific literacy connecting science learning with political and economic issues to find a model of science teaching for transformation. The authors suggest three levels of what they call humanistic science education considering different *visions* of scientific literacy with increasing complexity: (1) *Vision I*, which looks inward at science – its products, such as laws and theories, and its processes, such as hypotheses and experimentation, a science learning for later application; (2) *Vision II*, which looks outward in situations where science has a role, for example, in decision-making on socio-scientific issues (Roberts, 2007, p. 9), meaningful for an approach of science education for all; and (3) *Vision III*, science education for transformation. The first two were discussed by Roberts (2007) who distinguished between these two main orientations of scientific literacy. The last level can be understood based on Hodson (2011), who never used the term *Vision III* but acknowledged the term 'universal critical scientific literacy' and added a fourth level – engaging in socio-political action. These Visions will be relevant as an analytical framework to answer my first research question.

From reviewing recent literature (discussed in detail in Chapters 2 and 3), scientific literacy is still being recognised as the primary goal of science education (Osborne, 2023). However, a problem seen in the literature reviewed is that low-income countries that are part of the

OECD were(are) adjusting their educational curricula to achieve ‘adequate’ levels of scientific literacy defined by global standardised tests such as PISA (Dillon & Avraamidou, 2020).

Previously, the PISA framework used the term ‘science literacy’ to represent the primary outcome of science education. However, the new ‘*PISA 2025 Science Framework Draft*’ has chosen to phase out this term to avoid potential confusion. This decision could mark a significant shift in how we understand and assess science education.

Despite these intentions, the implications of this shift for educational policies across various countries remain unclear. The term ‘science literacy’ has historically shaped curricula, assessment methods, and policy discussions. For instance, some authors consider that students and, in some cases, teachers are not well-equipped with the essential elements of scientific literacy (e.g., She et al., 2019). This situation could have the effect of mimicking the education system of one country to implement it in another without questioning the specific educational context (Wang et al., 2019). Therefore, this might imply that teachers become immersed in or susceptible to accountability practices, affecting teachers’ autonomy, profession and practice (Holloway & Brass, 2018). Studies addressing the concept of scientific literacy typically do not critically examine the (dis)connection between science, politics, economics, socio-cultural backgrounds, history and, therefore, the distribution of power and wealth (Hodson, 2011). Consequently, conventional approaches to scientific literacy can be understood as a global standard where knowledge and learning are based on an unsustainable, individualistic (neoliberal) ideology that does not take into account the fundamental relationships between the individual and society, knowledge and power (Hodson, 2011). As such, these assumptions are usually framed within a deficit discourse, failing to account for local knowledge, understandings and conceptualisation of what scientific literacy is for, and, as Sammel (2009) argues, “pushing for assimilation of students [and teachers] into Western science ontology” (p. 653), its values and ways of being.

In the case of Chile, as I mentioned earlier, the last decade has witnessed an explosion of socio-environmental conflicts and ‘zones of sacrifice’ due to capitalist-extractivist and neo-progressive neoliberal development. This situation forces us to move towards collective action to strengthen environmental justice movements and develop alternatives to extractivist activities, roots of socio-environmental conflicts, considering global impact and responsibility in a shared world. In this sense, environmental literacies relating to fields of science might have a crucial role in promoting socio-scientific competencies towards radical transformation focusing on social and eco-justice (Reiss, 2003). Although some approaches in science education have followed this line (cf. Bencze, 2017; Levinson, 2010; Marks & Eilks, 2009; Sjöström & Eilks, 2018), there remain predominant visions of scientific literacy centred on a neoliberal paradigm and focused on promoting individual actions (Roth & Barton, 2004). The Chilean science curriculum is unsurprisingly influenced by the legacy of Pinochet's dictatorship, which prioritised neoliberal political rationality (Torres-Olave & Dillon, 2022). As a result, the values promoted in the curriculum documents emphasize individual responsibility, thereby limiting the scope for questioning structural elements or integrating traditional scientific literacy with political, social, and economic dimensions (Guerrero & Torres-Olave, 2022).

In this way, this thesis seeks to explore new and contextualised visions of scientific and environmental literacies based on conscientisation processes, fostering a critical awareness of ecological and societal issues and empowering learners to take action. This approach aims to promote a greater commitment to eco- and socio-justice, always through dialogue and collaboration.

Building on this foundation, I propose in this research a call to action rooted in scientific, environmental, and ecological awareness. Education for consciousness, as Freire (1970) describes, involves developing the ability to critically understand interpersonal connections, the meaning of being human, and analysing the causes and consequences of our actions in encounters with others. Thus, conscientisation refers to the possibility of "learning to perceive social, political and economic contradictions, and to act against the oppressive elements of reality" (p. 15). The concept of conscientisation will be examined in Chapter 4.

Based on these ideas, I propose to rethink the objective of science education in Latin America, reflecting on the deep meaning of scientific literacy in our region, unravelling the origin from which these approaches arise, analysing what should or should not be taught in sciences and thinking how various critical initiatives in the last decades give us hope to dream of visions of scientific literacy and environmental literacies in dialogue with the territorial, material and historical realities of our region, from an intersectional approach that sees in this type of literacy a constant search to contribute to social and environmental justice.

1.5.2 Exploring opportunities from outdoor education

I plan to explore – theoretically and empirically – opportunities to develop scientific and environmental conscientisation processes through the teaching and learning of science outside the classroom. Moreover, I plan to examine how collaborative research approaches in outdoor education contribute to the development of expertise among pre-service teachers. In outdoor education, the concept of 'expertise' is often defined as a combination of specialised pedagogical knowledge, skills, and competencies required for effective teaching and facilitating learning in outdoor settings (Beames, 2012). This expertise spans various areas, such as group management, specific outdoor pedagogical knowledge, practical skills for conducting and maintaining outdoor activities, safety management, and the ability to promote personal and social development through outdoor experiences (Priest & Gass, 2015). In the case of Chile, I believe that it is important to analyse how expertise in outdoor education among in-service teachers can be enhanced as a first step before exploring further opportunities for promoting critical approaches in science and environmental education. This preliminary decision is based on my personal experience as a science educator but also because of the extensive literature about the potential of going outside the classroom to feel, perceive and (re)connect with nature (Braund & Reiss, 2005; Louv, 2008). Besides, outdoor science education offers opportunities to observe scientific concepts within specific contexts and usually positively influences attitudinal, physical/behavioural, and inter-social constructs among students (Rickinson et al., 2004).

Outdoor science activities can connect teaching and learning with students' nearby contexts (Braund & Reiss, 2005). Reflecting on these opportunities, this project aims to connect these experiences outside the classroom with potential socio-environmental conflicts. In meeting students with communities and territories' conflicts through outdoor experiences, I propose to address student engagement, fostering on understanding of natural and social contexts around them (Gruenewald, 2003). This critical approach to outdoor science education seems to develop empathetic relationships with nature, which might be essential to start questioning and connecting social, scientific, political, and economic dimensions to promote environmental responsibility and conscientisation (Bartosh et al., 2010). As a result, different activities developed out-of-school-such as field trips, hiking, camps, and visits to natural reserves can develop students' awareness of and sensitivities to environments through direct personal experiences (Palmberg & Kuru, 2010). This process of conscientisation (Freire, 1970) might be a first step in promoting action and questions about links among science and environmental education and eco-justice. Participants in outdoor science activities in local contexts may also view themselves as relevant actors in their communities, as choice and change-makers, and become part of growing discourses or networks pro-eco-justice. Students and teachers affected by environmental conflicts in their communities should be allowed to deliberate and find solutions to problems by engaging with local sustainability principles and values (Cohen et al., 2015).

Using this approach, I propose using socio-environmental conflicts as scenarios in outdoor science activities aiming at reflecting and developing senses of interdependence with nature from critical theories (Andrade da Silva et al., 2020). I encourage using outdoor science activities to seek a deep understanding of relations between human, non- and more-than-human entities based on socio-environmental conflicts. My specific aim is to understand the network of actors within a socio-environmental conflict to be used as a pedagogical tool towards expanding eco-justice networks in the search of promotion of critical scientific and environmental literacies.

1.5.3 Collaboration and Collaborative and Participatory Research

Educational research traditionally aims to enhance teaching practices within schools and universities by generating relevant knowledge, with a growing shift towards engaging in Collaborative and Participatory Research (CPR). This approach rethinks how, why, and for whom we conduct research, emphasising research with people and communities rather than on or for them (Cohen et al., 2018; Vaughn & Jacquez, 2020). In view of this collaborative understanding of knowledge production, many scholars refer to their field of CPR as an 'epistemology', rather than a methodology (e.g., Fine & Torre, 2021; Lac & Fine, 2018). Engaging with CPR approaches, therefore, also entails a rethinking of what it might mean to design, participate in and collaborate on a research project. Such epistemologies, then, challenge academic assumptions about participation and are inspired by the transformative goals of public science (Fine & Torre, 2019). In this thesis, this process involves recognising teachers not just as implementers of policies but as co-researchers (Guerrero & Fernández, 2020). This reconfiguration respects the agency of participants and involves them deeply in the research process, promoting a culture of mutual respect, trust, and shared goals between educators and researchers. Such collaborative research models challenge traditional dynamics and advocate for 'third spaces' where knowledge creation is a shared process (Bhabha, 1994; Penuel et al., 2015).

Furthermore, the participatory nature of CPR critiques traditional academic practices, questioning extractivist epistemological perspectives focused more on data extraction than on understanding community contexts (Guerrero et al., 2019). This collaborative approach to doing research involves a significant shift from viewing educational research as merely academic to seeing it as intertwined with social and cultural action, thus reimagining the field as one of academic, social, and cultural action (Rodríguez, 2009).

A collaborative process is not an easy task. Engaging with CPR implies a reassessment of the design, impact, and aims of research projects, provoking new imaginations of what is possible in educational research (Fine & Torre, 2021; Glăveanu, 2023). This transformative approach calls for the transgression of traditional boundaries within higher education, potentially enhancing the professional development of both pre- and in-service teachers and contributing to more robust educational theories and practices. Through these partnerships and collaborative efforts, CPR seeks to foster an environment where university researchers (or science educators), pre- and in-teachers and others (e.g., park rangers in the case of this thesis) contribute jointly to new knowledge, helping to bridge the gap between school, university and other institutions.

CPR presents valuable opportunities for doctoral students to engage in change-oriented research that not only enhances the quality and impact of their studies but also deepens their understanding of educational contexts by incorporating a wider range of perspectives directly from the field (Brown, 2022; Vaughn & Jacquez, 2020). Such approaches facilitate a more nuanced view of school environments and pedagogical practices, reflecting diverse voices and ideas at the heart of educational praxis (Christianakis, 2010). CPR also introduces various practical and theoretical challenges that doctoral students must navigate (Guerrero & Dobson, 2024). However, I strongly believe that this inclusive and collaborative approach is essential for fostering a transformative educational research landscape that bridges the gap between academic theory and formal education practice and, with other scholars, I consider this approach as part of my axiological and epistemological positionality, highlighting the value of knowing and learning *with* (Haraway, 1988), tackling the elitism and competitivity presently inherent in academia.

1.6 Overview of methodology

The methodology of my thesis is divided into two stages. The first part is developed in Chapter 3 and is based on a systematic and critical literature review aimed at analysing critical approaches for scientific and environmental literacies in the last three decades. In doing so, I present a qualitative critical literature based on Bhattacharya et al. (2021) and incorporating typologies from Xiao and Watson (2019) and Barnett-Page and Thomas (2009).

This literature review began with a pilot search using broad keywords on Google Scholar and was followed by systematic searches in databases such as the Web of Science and SCOPUS. This process aimed to identify relevant studies in Spanish, English and Portuguese from which information could be extracted, synthesised, and discussed, thus providing a solid foundation for the empirical research.

The second stage of the methodology can be seen in detail in Chapter 4, where I describe the empirical section of the collaborative project focused on outdoor education as a potential scenario for promoting collective critical scientific and environmental literacies. This chapter is framed on CPR and involves a diverse group of participants, including pre-service and in-service teachers, scientists, and park rangers and me. This part of the project is supported by qualitative methods: interviews, focus groups, document analysis, dialogical seminars, and a field trip to 'El Morado', a natural park in Santiago, Chile. The methodology of the thesis articulates a comprehensive approach that integrates a critical literature review, qualitative research methods, and CPR principles to explore and address complex educational challenges within a socio-critical framework.

1.7 Thesis structure

Chapter 2 examines the critical role of science and environmental education in combating the global climate crisis. In this chapter, I discuss a critical approach inspired by Paulo Freire's theories on literacy and conscientisation, emphasising the need for educational strategies that promote scientific and environmental literacies contrasting the framework of the United Nations' Sustainable Development Goals (SDGs). The chapter critiques mainstream sustainability education for prioritising economic growth and technological solutions over social justice and environmental well-being, advocating instead for an educational model that addresses socio-political and ecological dimensions.

The chapter further explores Freire's dialogical and politically engaged method of literacy, proposing it as a means to foster critical awareness and transformative action in science and environmental education. Finally, the chapter highlights outdoor science education as an application of Freirean principles, promoting experiential learning that connects students with their local environments and socio-environmental issues. This approach aims to develop scientific and environmental literacies that empower students to understand and address the climate crisis effectively.

In **Chapter 3**, I address the first research question of this thesis, presenting the process and findings of a systematic and critical review of the literature from the 1990s to the present. In this chapter, I critically examine how critical approaches for scientific and environmental literacies have been conceptualised and critiqued over time. Particularly, I discuss the complex and evolving definitions of scientific and environmental literacies within the context of the global climate crisis in the last three decades. The chapter highlights the limitations of traditional approaches that often align with neoliberal capitalist agendas, emphasising the need for critical and context-specific educational frameworks. This chapter identifies a shift towards integrating socio-political, cultural, and ecological dimensions into these literacies – advocating for educational practices that foster critical awareness and transformative action– promoting dialogical and politically engaged methods to develop scientific and environmental literacies. I argue that such literacies should empower individuals to understand and address collectively socio-scientific and environmental issues within their specific contexts. The chapter also discusses the role of outdoor education and the incorporation of indigenous knowledge systems as vital components of a more inclusive and effective science education.

In **Chapter 4**, I present the empirical study methodology for my PhD research project conducted in Santiago, Chile, between December 2020 and September 2021. The chapter begins with a reflection on my positionality and philosophical stance, which informs the methodological decisions of the research. Then, I outline the challenges faced during the global COVID-19 pandemic and describe the hybrid research modality employed, providing details about the phases of contextual fieldwork, including participant recruitment, data production methods, and data analysis techniques. The chapter is structured into three main parts: my positionality and reflexivity, theoretical framework based on critical theories and Freire's concept of conscientisation, and a comprehensive account of the research methodology and timeline. Through the chapter, I emphasise the importance of Freirean critical pedagogy in developing scientific and environmental literacies, as a practical application of Freirean principles, promoting hands-on and contextually rich learning experiences.

Finally, I discuss the socio-critical paradigm and qualitative research methods used, highlighting the collaborative and participatory nature of the project. The recruitment process involved pre-service and in-service teachers, scientists, and park rangers, aiming to explore the potential of outdoor education to enhance critical scientific and environmental literacies.

At the end of this chapter, I also address some ethical considerations and challenges of conducting collaborative research during a pandemic, emphasising the importance of reflexivity and participant involvement in the research process.

Chapter 5 addresses the second research question of the thesis: How does collaboration enhance the expertise of pre-service teachers in outdoor education? The chapter analyses data from initial and final interviews, focus groups, and dialogical seminars conducted with pre-service teachers and all participants involved in planning and visiting El Morado National Park. The chapter begins by discussing the pre-service teachers' previous experiences and perceived expertise in outdoor education, highlighting a lack of formal training and opportunities at the university level. I identify significant barriers such as bureaucratic hurdles, a focus on indoor pedagogical methods, and limited collaboration opportunities during their teacher training period. The second part, examines the collaborative interactions among participants, including the integration of park rangers', science educators' and in-service teachers' perspectives. These dialogues highlight the value of interdisciplinary collaboration and the importance of acknowledging diverse identities and roles within the educational process. The final part discusses how collaboration during the planning and execution of the park visit enhanced the pre-service teachers' confidence and expertise in outdoor education. The chapter concludes by emphasising the importance of experiential learning and collaborative planning in developing effective outdoor education practices, and the need for structured guidance and interdisciplinary approaches to enrich pre-service teachers' expertise.

In **Chapter 6**, I address the third and final question of this thesis: To what extent can critical scientific and environmental literacy approaches be promoted through outdoor education? This chapter examines the empirical opportunities to apply and contextualise critical approaches during visits to 'El Morado' national park in San José de Maipo, Santiago, Chile. The chapter starts by exploring the potential of El Morado's geographical area for promoting critical scientific and environmental literacies, connecting these opportunities to the broader conceptual framework presented in earlier chapters. It highlights the relevance of the Maipo River and Santiago hydrological system, discussing the intersection of climate, socio-justice, and eco-justice within the context of Chile's neoliberal agenda. In this chapter, I also reflect on my own process of conscientisation and the importance of interdisciplinary and collective opportunities for promoting critical literacies through outdoor education.

The second part, titled ‘A monster in the park’, navigates and delves into the socio-environmental conflict caused by the Alto Maipo hydroelectric project. In this section, I analyse the network of actors involved, the impact of neo-extractivism, and the neoliberalisation of nature in Chile, reflecting on human-nature interdependence. This section includes insights from interviews and focus groups with pre- and in-service teachers, scientists, and park rangers, as well as an interview with the former coordinator of No Alto Maipo, an environmental activist leader. The final part, ‘A glacier as a more-than-human entity to develop conscientisation’, explores the role of the San Francisco Glacier in fostering critical awareness and interconnection. Particularly, I discuss how socio-political discourses around water management can be made pedagogical, emphasising the importance of understanding environmental conflicts and their broader implications for promoting critical scientific and environmental literacies.

In **Chapter 7**, I present a general discussion regarding research questions towards critical conscientisation in science and environmental education. In this final chapter, I discuss general conclusions, contributions to knowledge, implications for practice, theory, science curriculum, research, science outdoor education and for participants in this project. I close the chapter with limitations and possible future directions.

Chapter 2. Climate action and literacies from a Freirean approach

In the global context of the climate crisis, science education, particularly the promotion of scientific and environmental literacies, plays a key role in fostering collective climate action. This thesis aims to examine the development and potential integration of critical scientific and environmental literacies with the ultimate goal of inspiring action.

This chapter begins with a brief discussion of the significance and meaning of climate action. First, I analyse the definition of climate action from the United Nations' global framework for sustainable development and sustainability literacy in education. Next, I unpack the fundamental concept of literacy that is commonly used as a metaphor in different fields of knowledge. Then, given the relevance of literacy in climate action in education, I address several definitions of traditional or conventional conceptualisations of scientific and environmental literacies.

In the following section, while envisioning opportunities for action within the context of socio-environmental conflicts and (neo)extractivism in Latin America, I examine the approach to literacy proposed by the Brazilian educator Paulo Freire. I explore the potential link between a Freirean approach to scientific and environmental conscientisation from outdoor science education. Lastly, I discuss practical opportunities from collaborative-participatory research approaches to increase the expertise of teachers in planning and carrying out outdoor science activities.

2.1 The discourse of climate action from the SDGs

The current planetary crisis demands an education based on scientific and environmental literacies for climate action (González-Gaudiano & Meira-Cartea, 2020; Valladares, 2021). In this regard, the United Nations (UN) has emphasised the importance of education in empowering individuals to comprehend and tackle the consequences of the climate crisis, providing them with the knowledge, skills, and attitudes required to become active change agents (UN, 2023). Richard Kahn (2010), a critical theorist in eco-pedagogies, argues that:

> a critical education approach is necessary to understand how societies construct ideological, political, and cultural systems that promote climate action and ecological sustainability. (Kahn, 2010, p. xii)

Despite the crucial role of education in promoting effective action on climate change, there is still uncertainty about which strategies are most effective and how best to tailor them to different audiences and contexts (Quiroz-Martínez, 2023). This lack of clarity is compounded by mainstream sustainability discourses and social practices that often prioritise economic growth and technological solutions over social justice and environmental well-being, further complicating efforts to address the complex and ongoing challenges of the climate crisis. For instance, when we reflect on the role of education in the climate crisis, it is clear that climate action is a key thematic priority of the new global agenda adopted by the 193 Member States of the United Nations at the General Assembly in September 2015. The framework *Education for Sustainable Development*: *Towards achieving the SDGs* (ESD for 2030) seems to be crucial and the main route for promoting climate action (UNESCO, 2022). Indeed, Goal 13 is specifically dedicated to tackling climate action and is intertwined with the other 16 Sustainable Development Goals (SDGs) developed by the UN. One of the targets of Goal 13 is explicitly a call to improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning (UN, 2015).

The SDGs aim to promote sustainable economic, social, and environmental development (UN, 2021). They are supported by 169 measurable goals and 230 verifiable indicators that aim to offer comprehensive remedies for the interlinked and global challenges of sustainable development. These challenges include addressing inequality, climate change, extreme poverty, reducing unsustainable consumption patterns and environmental degradation, and enhancing institutional capacity (UN, 2021). Furthermore, it is important to note that the SDGs strongly support the defence of human rights and the health of the planet and its population. Despite criticism, the SDGs offer a new and valuable perspective compared to previous agendas, such as The UN’s Millennium Development Goals developed in 2000 by emphasising gender equality and the recognition and empowerment of women. The SDGs demonstrate a strong commitment to acknowledging inequalities within and between countries while promoting local economic growth (Gómez, 2017). Each objective is interconnected and aimed at promoting multilevel participation, spanning from the local to the global scale, to reinforce global solidarity and climate action. The objectives also integrate global summit education agreements that influence science education.

Specifically, in science education, the SDGs have become a central focus for many science educators, practitioners, and policymakers (Kyle, 2020). This focus and connection are evidenced by a literature review conducted by Maryanti et al. (2022) who analysed articles from 2012 to 2022 and found an intertwined relationship between science education and the

SDGs, with themes such as education, food, water, and health. In the book *Teaching Sustainable Development Goals in Science Education*, Kramer and Bauer (2021) propose new approaches to scientific and environmental literacies based on sustainability education, which strongly align with the global SDGs. According to Kramer and Bauer (2021), science education faces the challenge of the SDGs and ESD in different ways: (1) it plays a dominant role in equipping students with an adequate understanding of the complexity and causes of global challenges such as climate change, water scarcity, energy transition, or biodiversity loss; (2) it seeks to find new ways to integrate scientific knowledge and skills into real-world situations and elucidate ways to connect knowledge to sustainability-relevant values and attitudes; and (3) it has to overcome disciplinary boundaries to understand a problem comprehensively and, at the same time, provide discipline-specific knowledge and skills to solve the problem (p. ix).

Notwithstanding, the new conceptualisation of sustainability literacy in tune with the SDGs appears without criticism of this global agenda and its approach to climate action. Few authors are paying attention to the often apolitical and hegemonic perspective of ESD in the context of science education. For instance, for Scanara et al. (2021), ESD perspectives in science education do not assume the capitalist logic of economic growth as a pillar of a sustainable future. Herranen et al. (2022) argue that ESD must have a socio-political perspective. Similarly, Quiroz-Martínez (2023) points out that to promote the integration between science and sustainability education teachers need to understand what sustainability means in the first place based on its roots and discourses around SDGs.

Eskelinen (2021) notes that the SDGs maintain the tradition of utopian agreements promoted by the UN with substantive goals emanating from agreements, summits, and international conferences established years ago, which have been systematically breached without precise responsibilities, making non-compliance easy. As Nussbaum (2016) states, the complex architecture within which these designs have been developed imposes significant restrictions that may hinder the ability of this new agenda to accomplish its intended goals of creating a better planet for future generations. Gómez (2017) continues by saying that although the novelty of the universal component of the SDGs is repeatedly emphasised, it should be noted that of its 169 goals, 27 of them are only applicable to ‘developing’ countries, representing only 16% of the total. This argument also calls into question the universal dimension of the entire 2030 Agenda. For example, Goal 16 commits all states to “promote peaceful societies,” while Western countries that are signatories to the agreements are the main weapons sellers in the world. Goal 13 requires countries to adopt urgent measures to combat climate change. However, some countries deny that this phenomenon even exists or have been absent in the last discussions to reduce carbon emissions in the last Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change in 2021.

Some critics argue that the SDGs support and sanctify dynamic sectors of the economy through free trade and an unrestricted private sector without requiring basic compliance with United Nations conventions and agreements, such as the Universal Declaration of Human Rights (UN, 2023). Likewise, the ethnocentric vision projected by the SDGs as a vision of scientific and environmental literacy is also rightly criticised for placing not a few advances "under the leadership of developed countries", as if they were a role model and mimetic for poor countries. Gross and Rovira (2019) argue that the SDGs contain contradictions and tensions, including the fact that developed countries are expected to lead the way in sustainable consumption and production. However, their own production and consumption patterns are often unsustainable. This criticism is included explicitly in some sensitive goals, such as 12.1, which speaks of "applying production and consumption models under the leadership of developed countries", even though a large part of the production and consumption patterns of developed countries are based on unsustainable models or extractivism, capitalism, and neoliberal economies.

Another point that has aroused criticism is the support that the SDGs and the United Nations give to public-private partnerships, contained in their Goal 16.16, without raising demands for transparency, accountability, respect for basic social and environmental norms, or respect for basic human rights (Gómez, 2017). This argument facilitates the fragmentation of global governance, the weakening of representative democracy and the emergence of new socio-environmental conflicts. For instance, just for Latin America the Global Environmental Justice Atlas registers a total of 1,048 socio-environmental conflicts (Temper et al., 2015). Therefore, multiple contradictions lead us to doubt the concept of climate action for proper eco- and socio-justice in education due to the inherent ideological contradictions of SDGs. Consequently, the recent focus of scientific and environmental literacies on education for sustainability seems inappropriate for the diversity of contexts.

The climate struggle and the global planetary crisis should be recognised primarily as a consequence of deeper, systemic, and methodical issues such as capitalism, colonialism, (neo)extractivism, and patriarchy (Huber, 2022; Svampa, 2019). As Huber (2022) points out, "while capitalism, for the first time, tears the majority of humanity away from a livelihood relationship with the land and ecological systems" (p. 40), this situation is forcing us to establish a new conscious and sustainable relationship with nature.

A process of conscientisation in sustainability education demands the recognition of "the real cause of the climate crisis in which a small minority of owners control vast flows of energy, resources, and, indeed, emissions – all directed toward one goal: profit" (Huber, 2022, p. 55). This process also means finding a new approach in science and environmental education to reconstruct our relationship with nature at a global and local scale. The need for critical and local approaches to sustainability literacies from the Global South is urgent. It allows us to deconstruct the underlying power structures perpetuating the global crisis and develop strategies to promote eco- and socio-justice. While this sounds challenging, the next sections explore opportunities from a Freirean sense of the concept 'literacy' to develop a process of conscientisation in science and environmental education.

2.2 Fundamental and Freirean senses of literacies

The metaphor of literacy is highly complex and can be defined and interpreted in different ways depending on social, cultural, and political contexts (Freire, 1970; Gee, 1996). In the context of a climate emergency that strains nature and humanity, it is essential to rethink and contextualise science and environmental literacies to promote skills, aptitudes, and competencies that empower individuals and communities to understand the interconnections between living organisms and their local environment, and to take action on climate change. In this sense,

> humanistic science perspectives could be seen as fitting within a Freirean view since they establish the goal of scientific literacy to insert the students into the world to transform it, which is one of Freire's educational principles" (Santos, 2007, p. 368).

However, previous research has shown that some conventional visions of sustainability, and scientific and environmental literacies are disconnected from this global catastrophe and have been controversially supported by neoliberal agendas that underpin 21st-century global economies (Martinez-Alier, 2022; Reid, 2019). Neoliberalism is connected to the environment through the privatisation and commodification of 'resources' such as forests, water, and biodiversity, payments for environmental services, deregulation, and cuts in public spending on environmental management, and the transfer of environmental management to local or non-governmental institutions (Harvey, 2005; Robbins, 2012). To address the previous situation, it is important to (re)define scientific and environmental literacies in their fundamental senses to question what we really mean by literacy in a global planetary crisis, and integrate science into a broader political debate.

Norris and Phillips (2003) argued that a solid foundation in the fundamental sense of literacy is a prerequisite for developing a comprehensive understanding of scientific concepts, and the fundamental sense of literacy is central to scientific literacy. They also highlighted that "individuals who possess such literacy skills are essential for the existence of science" (p. 236). As a result, it is important to understand the meaning of the fundamental metaphor of literacy to examine how prioritising basic literacy skills impacts the education and learning of science –and given the climate crisis– its potential connection with environmental education and environmental and non-hegemonic approaches for sustainability literacy. Non-dominant sustainability perspectives that have primarily emerged from regions in the Global South (Kothari et al. 2014) put forth alternative sustainability solutions that reject the notion of infinite growth on a planet with limited resources. These perspectives also aim to address issues of social inequality and justice.

In 1966, the United Nations Educational, Scientific and Cultural Organisation (UNESCO) funded the Experimental World Literacy Program and defined literacy as a fundamental human right (UNESCO, 2008). Therefore, UNESCO added another concept to the definition called 'functional literacy', which refers to the ability to engage in all those activities in which literacy is required for effective functioning with someone's group and community, and also to enable them to continue to use reading, writing and calculation for their own and the community's development (UNESCO, 2008). Beyond its conventional concept as a set of reading, writing and counting skills, literacy is now understood by UNESCO's definition as a means of identification, understanding, interpretation, creation, and communication in an increasingly digital, text-mediated, information-rich and fast-changing world. Literacy is a continuum of learning and proficiency in reading, writing and using numbers throughout life and is part of a larger set of skills, which include digital skills, media literacy, education for sustainable development and global citizenship, as well as job-specific skills (UNESCO, 2023)

UNESCO has been striving to achieve the goal of universal literacy since 1946, with the belief that obtaining and improving literacy skills throughout one's life is an essential component of the right to education and can bring immense empowerment and advantages. In the same line and according to the definition provided by the OECD, literacy refers to the capacity to read and write at a competent level. This description highlights the comprehension, utilisation, assessment, introspection, and involvement with written information in daily routines at home, work, and within the community to fulfil individual aims, augment knowledge and aptitude, and engage in societal activities (PISA, 2018). However, the relationship between proficiency and literacy skills is tight when it comes to a particular field of knowledge, like Western science, and a high degree of sophistication within it (Norris & Phillip, 2003). Mackey (2004) contends that literacy has never been a fixed set of skills and must be 'historically contingent'. Likewise, Kalman (2015) asserts that literacy is not autonomous or an independent variable. Rather, it is deeply intertwined with other aspects of social life and necessitates urgent political and economic policies and actions on a different level for marginalised populations. Becoming literate depends on knowledge of social and political conventions. Thus, in the process of unpacking the concept of literacy, Paulo Freire, the distinguished Brazilian educator, offers an inspiring example of critical approaches to metaphor of (scientific and environmental) literacies (Freire, 1973; Macedo, 2006).

Freire's conceptualisation of literacy as a tool for social change and empowerment has inspired numerous scholars who have applied his framework in various educational contexts. Many authors have built upon Freire's work and integrated his approach into literacy in science education. For instance, Santos (2007) extends Freire's literacy framework to the field of scientific literacy. He emphasises that scientific literacy should not only focus on the acquisition of scientific knowledge but also on how individuals use that knowledge within social contexts. Santos argues that scientific literacy is crucial for citizenship, enabling individuals to critically engage with science, technology, and society. He echoes Freire's notion of literacy as a social practice, emphasising that scientific education empowers individuals to participate in democratic processes and make informed decisions in their daily lives.

Bertoldi (2020) explores the conceptual differences between *alfabetización científica* and *letramento científico*, drawing deeply on Freire's approach to argue that scientific education must transcend knowledge acquisition and lead to critical social engagement. In short, *alfabetización científica* is about learning the basics of science, while *letramento científico* involves using that knowledge critically and actively in a social context. In this sense, *letramento científico* is in tune with Santos's definition of scientific literacy since it involves applying scientific concepts in social practices, aligning with Freire's perspective that education is never neutral but either perpetuates power structures or empowers individuals to challenge them. This term goes beyond just understanding or acquiring basic scientific knowledge; it involves the ability to apply that knowledge in real-world contexts, to critically analyse scientific issues, and to engage with them in social and civic practices. Bertoldi and Santos thus advocate a form of scientific literacy that promotes critical engagement and societal transformation.

Seiler and Gonsalves (2010) explore the application of Freire's liberatory pedagogy in science education, particularly in marginalised communities. They argue that Freirean pedagogy, with its emphasis on dialogue and critical consciousness (*conscientização*), can transform traditional science classrooms into spaces where students actively co-construct knowledge. This approach counters the 'banking model' of education, which Freire criticised for treating students as passive recipients of information. In their study of African American high school students, Seiler and Gonsalves document how a Freirean, student-centred approach fostered critical thinking and allowed students to take ownership of their learning.

Similarly, Calabrese-Barton (1998) has drawn on Freire's ideas to critique traditional approaches to teaching science in marginalised communities. She emphasises the need for situated learning – another Freirean concept – where scientific knowledge is not abstract but directly linked to students' lived experiences. This approach resonates with the concept of *letramento científico*, as it prioritises the application of scientific knowledge in ways that are relevant and empowering for students from underserved backgrounds. Another scholar, Moacir Gadotti, has applied Freirean pedagogy in environmental education. Gadotti (2008) uses Freire's framework to argue that environmental literacy should focus on critical thinking and collective action, much like *letramento científico*. He emphasises that individuals must understand scientific concepts within the larger socio-political context to address global environmental issues, reinforcing the transformative potential of scientific literacy.

These scholars, among others, have built on Freire's foundational ideas to create educational frameworks that emphasise the role of literacy – both traditional and scientific – in promoting social justice, empowerment, and critical engagement with the world.

Freire developed a successful adult literacy program based on dialogical processes, which enabled thousands of people in Latin America and Africa to become literate in a short period of time. During his exile in Chile between 1964 and 1969, Freire conducted literacy courses that caught the attention of UNESCO for their effectiveness in reducing the illiteracy rate and his approach to literacy for freedom (UNESCO, 1973). Similarly, a governmental program under Freire's supervision in Tanzania doubled the literacy rate in 10 years. What makes Freire's approach revolutionary is not only its speed of teaching reading and writing but also its political engagement of students in the struggle for democratic reforms that their countries require (Dos Santos, 2007). According to Cabaluz and Areyuna-Ibarra (2020), Freire's perspective on literacy goes beyond functional literacy, focusing on awareness, 'dialogicity', and liberation, using 'generative words' instead of those chosen by the educator. According to Freire (1970) and Macedo (1994), generative words refer to a method of teaching reading and writing for conscientisation. This approach highlights using key vocabulary words relevant to the learners' experiences and context. Rather than teaching isolated words, the focus is on using words that are 'generative', meaning they can be used to create new meanings and ideas in the learners' lives. This approach helps to connect literacy learning with the learners' social and political realities, promoting critical thinking and a sense of empowerment. Conscientisation is a term coined by Paulo Freire which refers to a transformative process of critical awareness-raising through which individuals gain a deep understanding of the social, economic, and political factors that influence their lives (Freire, 1979). It entails developing a critical perception of the world in which one lives and recognising the systematic forces of oppression and inequality that shape it. Through conscientisation, individuals become aware of their own power and agency to effect change in their lives and society. This process is central to Freire's approach to education and literacy, which emphasises critical thinking, dialogue, and social action. I will discuss in depth this concept in Chapter 4.

In essence, Freire's educational approach to literacy is humanistic, emphasising the importance of addressing the actual conditions of human existence, with a specific focus on oppressive situations. Another basic principle of his pedagogy is dialogue. Freire (1979) stated that it is impossible to educate critical consciousness without the dialectic, historical and material process involving dialogue among individuals. For him, anybody could educate anybody; men and women are educated by each other, mediated by the world (Freire, 1970). This idea seems to introduce a collective idea of literacy that – from my positionality – might be applied in science and environmental education and it seems to be a gap in the literature about literacies in sustainability, science and environmental education.

Freire (1972) pointed out that true or real literacy is praxis, reflection, and human beings' action towards transformation, He also conceived all the previous definitions regarding literacies as *naïve* notions. Normally, illiteracy is seen as a harmful or dangerous 'herb', something to be eradicated because it is sometimes seen as an illness – a manifestation of incapacity among people, ignorance or poor intelligence. On the contrary, Freire claims that illiteracy is an explicit phenomenon, a mirror of the structure of a society in a specific historical moment (Freire, 1970). Therefore, literacies or illiteracies might not be analysed as mechanical acts without a specific power structure or as an act in which the educator only deposits (on illiterates) words, concepts, theories, or ideas aiming at the participation of people in social life. On the contrary, Freire considers these traditional methods of literacies as domesticating practices and instruments that typically promote alienation among people. In this sense, conventional approaches to literacies in different fields of education also aim to attend to political interests to bring under manipulation individuals without integrating their realities, histories and specific contexts (Freire, 1978). To understand the next section in this chapter, it is important to consider the renowned 'method for literacy' based on three main stages (Freire, 1976, p. X):

1. Investigative and preparatory work to identify the learners' social situation and to prepare materials and agendas;
2. A discussion of the learners' existential situation by analysing some words (called by Freire generative words) and a series of pictorial representations of their adult culture, and
3. A syllabic combination by using words, starting with the reading of the generative words, and the construction of new ones, continuing, however, the literacy process integrated with an exploration of contexts from which generative words emerged.

These stages can be summarised as reading the world, sharing the world with others, and constructing and reconstructing the world. According to Santos (2007), Freire's approach to literacy involves the exploration of culture. The process of acquiring literacy begins with understanding the culture of the students, which Freire calls 'circles of culture' (Freire, 1970). The next step involves the teacher selecting a cultural aspect for student discussion after researching the group's culture. The use of generative words and pictures that are relevant to the student's cultural context is employed in this process. Students utilise these words and pictures to encode and decode the world around them, creating and re-creating their understanding of it. The objectives are to help students gain knowledge about their environment and to promote conversations about anthropological, social, and political concerns (Santos, 2007).

Aikenhead (2006) described several features of a humanistic approach to science education that overlap with Freire's perspective. Aikenhead's (2006) list of characteristics of humanistic science education included several points that are similar to Freire's ideas. For instance, three characteristics (induction, socialisation, and enculturation) emphasise the importance of students becoming part of their local, national, and global communities increasingly shaped by science and technology (cf. Biesta, 2010). Additionally, learning in a humanistic approach involves interacting with the everyday world. It encompasses "intellectual achievement, personal growth, the development of new self-identities, the recognition of socio-political power, and, perhaps, practical or social action" (Aikenhead, 2006, p. 3).

In this sense, humanistic science perspectives could be seen as fitting within a Freirean view since they establish the goal of scientific literacy to insert the students into the world to transform it, which is one of Freire's educational principles that contributed to the reproduction of dominant social structures in society. Aikenhead (1996, 2000) warned that educational approaches that present science as a monoculture – the Western science of a privileged elite – could inadvertently and tacitly privilege the dominant social, economic, and political class in society, creating, implicitly an agenda of the status quo. In his studies on cross-cultural science education, Aikenhead (1996, 2000, 2006) supported the point that science itself is a subculture of Western or Euro-American culture and that school science is a subculture of the school culture. Rodríguez (2019) incorporated the idea of conceiving literacy as a critique. When the construction of subjectivities and the transformation of reality are considered, scientific literacy should also take on cultural and social transformation. As Rodríguez (2019) mentioned, when making the relation between linguistic and critical scientific literacy, reading is not merely decoding what is written in a text but understanding the relationship the word has with its everyday world. The same would apply to scientific content, where it would not be enough to understand scientific and ecological concepts if it does not lead to understanding reality, so the relationship with the context is essential.

In the next section, I will unpack in more detail the conventional concept of scientific and environmental literacies to analyse how the fundamental meaning of literacy permeates the metaphors of literacies in science and environmental education.

2.3 Scientific and environmental literacies from conventional approaches

2.3.1 Scientific literacies

Scientific literacy is a wide concept embracing many historical and extensive educational themes that have shifted over time and established it as an analogy or metaphor between fundamental literacy starting in the late nineteenth century and the extension movement of scientific and technological education (Aikenhead, 1985; Bybee, 2015; Hodson, 2010; Laugksch, 2000; Norris & Phillips, 2002; Osborne, 2023; Roberts, 2007; Roberts & Bybee, 2014).

The first time the concept of scientific literacy appeared was in 1945 (Rudolph, 2024). Then, the first definition of scientific literacy as a goal of science education appeared in papers by Paul Hurd (1958) in his article 'Science literacy: Its meaning for American schools' and Richard McCurdy (1958) in his work called 'Towards a population literate in science'. According to Hurd, revolutionary changes in the nature, ethos, and practice of the sciences reveal a need to regularly re-examine the traditional purposes of education in the sciences (Hurd, 1998) and, comparably to the concept of literacy in the previous section, a citizen who is 'scientifically literate' is someone who can participate democratically in many national democratic decisions about science and technology in modern life. However, in this definition, it might be difficult to imagine Hurd or McCurdy thinking about contexts other than Global North or even more difficult to imagine how the authors were considering indigenous science or the idea that every culture has its own science and understanding of the world.

Pella and colleagues defined scientific literacy as the ability to understand basic concepts of science, the nature of science, ethics and interrelationships of science and society and differences between science and technology (Pella et al., 1966). Similarly, Wellington (2001) analysed the literature summarising the debate into three categories of scientific literacy, which followed the decision to include (or not) specific topics in the curriculum: practical (utilitarian arguments), civil (citizenship arguments) and cultural (intrinsic value):

(i) *Practical and utilitarian dimension*, because it is knowledge necessary to solve life's everyday problems or to prepare people for careers and jobs that involve science and to develop a 'scientific attitude'.

(ii) *Civic or citizenship dimension*, because it is knowledge necessary to play a full part in key decision-making in areas such as health, natural resources, energy policy and environment. This definition is still being used by some authors in China (e.g., Wu et al., 2018).

(iii) *Cultural or intrinsic value* because it involves knowledge about ideas in science that represent our major cultural heritage and promotes making sense of natural phenomena.

Thus, even though the concept has been gradually reconceptualised, to such an extent that it is considered as a poorly and even fuzzily defined concept, scientific literacy has become an internationally recognised and contemporary educational slogan that aims to (re)direct educational goals (Laugksch, 2000, p. 71).

After general criticism from scholars about attempts to define scientific literacy, these three dimensions were reconsidered. For instance, (i) adding more or fewer categories such as methodological science literacy, professional science literacy, universal science literacy, technological science literacy, amateur science literacy, journalist science literacy, science policy literacy and public science policy literacy, each of them with a specific role in society (Branscomb, 1981); (ii) discussing new forms of scientific literacy, such as functional scientific literacies, true scientific literacy, nominal scientific literacy, multidisciplinary scientific literacies (Bybee, 1997; Fensham, 2002; Shamos, 1995); or, (iii) as Roberts (2007) pointed out, presenting only two visions for scientific literacy: *Vision I* which looks inward at science, its products, such as laws and theories, and its processes, as hypotheses and experimentation unfold; and *Vision II* which looks outward in situations where science has a role, for example in decision-making on socio-scientific issues (Roberts, 2007, p. 9).

Vision I refers to *science for future scientists*, as defined by Roberts in 2007. This approach focuses on the conceptual knowledge of science, its internal processes, and methods; however, according to Valladares (2021), *Vision I*, presents science without consideration of its societal implications. Science education, based on this approach, aims to provide a theoretical understanding of essential scientific phenomena, typically distant from everyday life, with a focus on the training of future professionals related to the natural sciences (Massarini & Schnek, 2015; Valladares, 2021; Vilches et al., 2004). According to Hodson (2011), this understanding of scientific literacy aligns science education with preliminary instruction or economic growth orientation. Besides, the central focus is on conceptual development and learning the scientific culture, while issues related to the nature of science, scientific skills, procedures, or attitudes are de-emphasised. This approach to scientific literacy rarely incorporates teaching strategies that link scientific knowledge with everyday science or facilitate a transition from traditional teaching models to socio-constructivist approaches, resulting in a dogmatic or disconnected approach to teaching natural sciences, as described by Fourez (1997). This view of science, which is out of context and not geared towards solving ‘real-world’ problems or transforming society, could contribute to students’ low interest in learning natural sciences and hinder the development of skills necessary for active citizenship in democratic systems (Tàbara & Jiménez-Aleixandre, 2013).

Vision II addresses the interrelation between science and how scientific knowledge is linked to everyday issues (Roberts, 2007). The aim of *Vision II* is the application of scientific knowledge in life and society, and it seeks to explore situations in which science has a role outside of scientific processes (Valladares, 2021). For example, it applies to decision-making on socio-scientific issues or controversies (Roberts, 2007). This vision, as proposed by Fourez (1997) and Gil and Vilches (2001), promotes the slogan of ‘Science for All’ in which science education must be useful for people to understand everyday phenomena related to scientific and important social issues. This is how the teaching of science begins to touch spaces that were not considered in the previously explained vision. From this vision emerges the need to use teaching or ‘didactic’ models that are related to students’ contexts and the development of critical thinking skills so that students and future citizens can make personal decisions on relevant scientific issues.

In addition to *Vision I* and *Vision II*, there is a third vision of scientific literacy, also known as *Vision III*, which was introduced to the field for the first time by Glen Aikenhead in 2007 and later discussed by Hodson in 2009. This vision represents a new focus on scientific literacy that connects science learning with political and economic issues. *Vision III* not only enables individuals to understand scientific knowledge but also encourages them to establish values and higher ethics for decision-making in collaboration with others (Hodson, 2011).

Sjöström and Eilks (2018) suggest that *Vision III* aims to transform scientific knowledge into a critical practice that promotes eco-justice, emancipation, and transformation. They propose three levels of humanistic science education that incorporate current ideas from the eco-reflexive *Bildung* concept and consider different dimensions of scientific literacy with increasing complexity. In this approach, scientific knowledge is transformed into a critical practice that emphasises the ability to build collective actions to solve real problems. *Vision III* places particular emphasis on the common good and justice, arguing that weak or fragile scientific literacy could lead to technocratic societies where citizens do not participate democratically in science-related matters, ultimately leading to weak political systems. Finally, it is worth mentioning that the discussion, mainly in the Global North, is an ongoing one with many authors describing new visions such as: *Vision IIa* and *Vision IIb* (Lundqvist et al., 2013), *Vision 1.5* (Schwartz et al., 2023) and *Vision IV* in STEM education (Jones et al., 2024). *Vision IIa* focuses on the practical use of scientific knowledge in everyday contexts, while *Vision IIb* extends this to its broader societal implications, such as fostering participation and engagement. Within *Vision IIb*, the goal of science education is to provide students with the scientific knowledge and skills necessary to take the initiative, make informed choices, and engage actively in scientific discussions, including those on socioscientific issues (Lundqvist et al., 2013). *Vision 1.5* serves as a middle ground, balancing these two approaches. However, in my opinion, Schwartz et al. (2023) overlook a substantial part of the broader discourse on scientific literacies within the literature. This gap excludes many influential studies and perspectives, including critical insights associated with Vision III concepts. Therefore, *Vision 1.5* maintains a strong foundation in scientific content and the core principles of *Vision I*. On the other hand, *Vision IV* in STEM education expands upon the socio-political aims of previous frameworks, particularly those of Sjöström and Eilks (2018) and involves a politically engaged, activist-oriented approach, where students learn through acting and motivating others to reflect on their societal impact (Jones et al., 2024).

In the case of Chile, the national curriculum in primary school is based on *Vision II* (Guerrero & Torres-Olave, 2022; Salinas et al., 2022). Moreover, only five per cent of learning goals in the Chilean curriculum are connected to climate crisis content, while most of the learning goals are from science as a school subject. The curriculum on climate change is closely linked to concepts such as sustainability, biodiversity, global warming, and the climate system. Curriculum proposals in science explicitly connect to other school subjects, such as mathematics, that have fewer learning goals connected to climate change topics. Activities to be developed using the science curriculum appear to have more prescriptive elements at higher levels of schooling. Particularly, climate action is promoted with more emphasis in the Chilean curriculum in the last two years of schooling, where "the new subject called 'Science for Citizenship' offers a different approach to understanding science than the curriculum for the previous years of schooling" (Salinas et al., 2022, p. 16).

In Guerrero and Torres-Olave (2022), we aimed at answering the following research question: 'How are the different visions of scientific literacy operating and being promoted within the Chilean science curriculum?'. This question was addressed using the three-dimensional critical discourse analysis (CDA) model of Fairclough (1989) which is based on three complementary dimensions: (i) as a text, (ii) as a discursive practice, and (iii) as a social practice. CDA is understood as a theoretical model and methodology, seeking to unveil how discourse mediates in social situations by analysing the vocabulary, clauses, metaphors, and frequency of words (Fernández et al., 2016). In doing so, we identified two different approaches to scientific literacy within the two documents. All translation from Chilean documents were done by me. We concluded that two different paradigms and Visions coexist in the national curriculum. These findings can be seen in Figure 1.

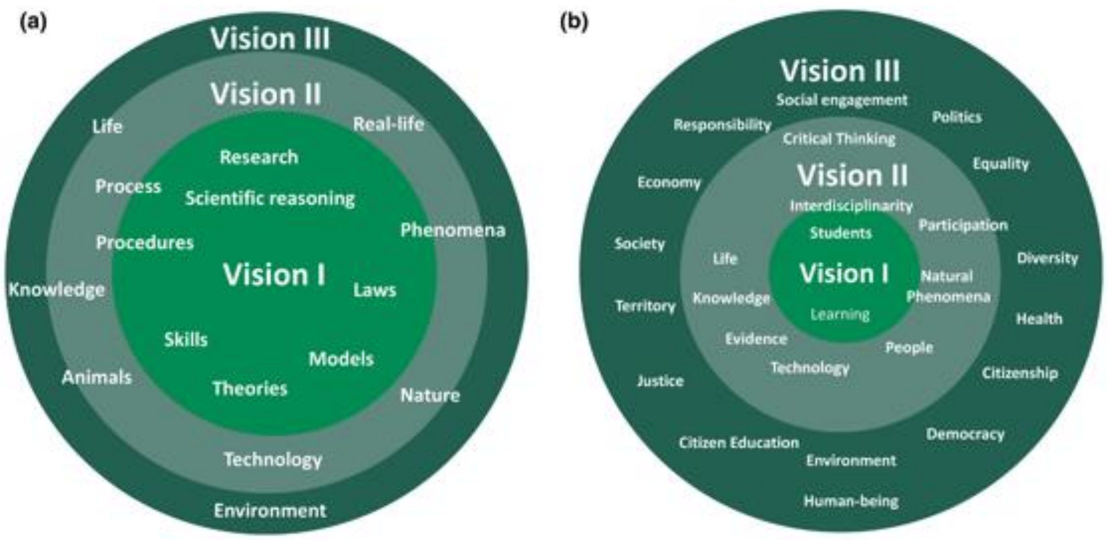

Figure 1. Two models of scientific literacy and word frequency presented in different levels of the Chilean curriculum: (a) curriculum plan of secondary level (first cycle) from 7th grade (12-year-old students) to 2nd grade (15-year-old students), developed in 2016; and (b) the current science curriculum of secondary level (second cycle), third and fourth grade (16- and 17-year-old students), developed in 2019.

At the textual level, both documents explicitly refer to the concept of scientific literacy. The first document of 2016 states that doing science at the school level translates into building or reconstructing scientific concepts based on scientific research that can be experimental, non-experimental, or documentary, among others (p. 130). It is emphasised that the student must understand the laws and theories that best explain natural phenomena. Additionally, the document states that the curriculum should emphasise the scientific literacy of the students "which should promote the acquisition of basic concepts and ideas of science to understand experiences and close situations and, thus, generate creative solutions for everyday problems" (p. 130). Thus, at the level of semantics and vocabulary, we find an amalgam between *Visions I and II*. This result can be seen in the following:

> By becoming literate in science, students will be able to reason about facts as diverse as the operation of instruments made from scientific discoveries, the reproduction and feeding of living beings, or changes in matter due to different forces. (p. 41)

The conceptualisation of scientific literacy in this document is complemented by a semantic field focused on digital literacy, where information and communication technologies are considered an essential part of scientific literacy and a fundamental competence among students. For example:

> Students must acquire the concepts and ideas – from their own experiences – of the exact sciences and their method that will enable them to understand and explain the physical world, use technology in an informed and autonomous way, and assess empirical evidence as a method of analysis and approximation to knowledge. (p. 131)

It is noteworthy that the vision here is based on autonomy and the personal experiences (individualistic) perception of the student without a connection to local or global problems. Community participation is absent, suggesting individualism as the hegemonic discourse. Moreover, and in regard to the second dimension of CDA, at the level of the inter-texts, the curriculum was developed based on curricula from other countries. Curiously, the list of references is composed of documents from countries with different educational contexts and backgrounds, not only for society as a whole but also for the circumstances in which teachers work.

Finally, other frequent concepts that accompany scientific literacy are research, skills, knowledge, models, procedure, theories, forms of scientific reasoning, concepts, empirical evidence, analysis, understanding of phenomena, science and technology, the reasoning of mathematics, methods, knowledge, and competences, among others. The second document (2019) states: “a scientifically literate citizen must develop the ability to think critically, to participate and make informed decisions based on the use of evidence” (p. 42).

The scientific literacy approach is merged with science for citizenship, which seeks to promote an integrated understanding of complex phenomena and problems in our daily lives, to educate a scientifically literate citizen. In the same vein, the concept is accompanied by an interdisciplinary aspect with a more critical and active language and a vocabulary where the agency of students in society and the world is considered, for example:

> Students acquire the ability to apply reasoning, concepts, and procedures of science to understand daily experiences and situations and propose creative and viable solutions to

> problems that may affect people, society, and the environment, in local and global contexts. (p. 42)

Thus, the new curriculum seeks to develop skills and attitudes necessary for scientific research, understanding the central knowledge of science, relating science and technology with society and the environment, and establishing integration between topics of science and other disciplines. Thus, science is no longer understood as impervious to social processes, but rather as part of them so that students are considered active subjects who can question its role. Another significant sentence that can be interpreted as positioned from a critical scientific literacy or *Vision III* (Hodson, 2011) and that could serve as a guide for the promotion of critical scientific agency (Schenkel & Calabrese-Barton, 2020) is:

> Assess the importance of integrating the knowledge of physics with other sciences to analyse and propose solutions to current problems, considering the ethical, social, and environmental implications. (p. 195)

At a semantic level, this document presents the meaning of scientific literacy as opportunities to “critically analyse social, economic, ethical and environmental implications of problems related to public controversies that involve science and technology” (p. 179). This document addresses a critical scientific literacy approach through projects and research. For instance, with activities about “designing local projects, based on scientific evidence, for the protection and sustainable use of Chile’s natural resources, considering energy efficiency, emission reduction, treatment of water resources, ecosystem conservation or waste management” (p. 10). Likewise, one aim of the environment and sustainability module is “to model the effects of climate change on various ecosystems and their biological, physical and chemical components, and evaluate possible solutions for their mitigation” (p. 52). From the third dimension of CDA, this document explicitly emphasises and moves towards a collective and socio-political vision of scientific literacy. Words related to the analytical category *Vision III*, with a discursive and social practice based on democracy, society and social justice, are repeated across the document. Running the tool word frequency query and text search, some recurrent concepts are equality, diversity, health, environment, citizenship, learning, distribution, politics, and teachers.

In terms of intertextuality, this critical approach is not casual since this document includes the citizen education subject for the first time, cross-linked with the rest of the science curriculum. For example, it states that the “current environmental scenario in the world, especially climate change, demands the participation of a citizenry educated in these issues and possessing the ability to advance towards sustainability” (p. 56). Moreover, the document suggests that people must make good consumption, investment and saving decisions to satisfy their present and future needs. This paragraph states: “understanding that there are human needs whose satisfaction is not always achievable individually and that certain conditions of life in society are required that a democratic state must promote, support and stimulate” (p. 56).

Thus, the transition – given as natural – from one level to another produces tensions and pushes teachers and students to move to a new approach to science education that is closer to *Vision III*. These tensions show a difference between concepts within these two documents (see Figure 1). In this thesis the neoliberal rationality of scientific literacy is seen as permeating the curriculum and thus the associated values of science education, in particular individual responsibility for scientific aspects. As such, changes lie within the individual and their behaviour. In turn, science is presented as if it is impervious to social or political dimensions. Student agency is limited to an uncritical relationship with the world without considering power structures that may hinder it. For example, Chile’s unequal access to water or the effects of industrial companies’ pollution on people’s lives are issues that could not be explored and problematised through this understanding of scientific literacy. Questions therefore arise regarding how to move towards a critical approach to scientific literacies.

From reviewing recent literature on the subject, conventional approaches for scientific literacy are still being identified and recognised as the main goal of science education (Bybee, 2015; Osborne, 2023). According to Osborne (2023), scientific literacy essentially is “a term that points to a diverse set of goals that educators, scientists, and politicians want for citizens and society that fall under a loose but recognised mantra” (p. 786). Therefore, societies often use the argument for scientific literacy as a legitimate goal that justifies educating all students in science. Despite this approach, there is not a global consensus on the meaning of the term scientific literacy (e.g., Vieira & Terneiro-Viera, 2016). Indeed, according to Queiruga-Dios et al. (2020), the definition of scientific literacy is highly complex, as this concept is continually changing and depends upon its social, cultural, and political contexts. Even though many efforts have been made to delineate the concept, none has produced a universal acceptance because to speak of scientific literacy is basically to speak of science education itself (Osborne, 2023; Queiruga-Dios et al., 2020).

Established visions of scientific literacies determine, at the same time, the logic that should be considered in school curricula documents and the approaches and strategies for teaching and learning natural sciences that would be implemented (Guerrero & Torres-Olave, 2022). Hegemonic visions of scientific literacies also permeate the curriculum from neoliberal rationality. Therefore, the values it promotes stem from an individual responsibility that does not allow questioning of structural elements nor integrating scientific knowledge from socio-political, economic, environmental, or bioethical dimensions. In addition, the science curricula in various countries of Latin America – with exceptions such as Argentina and Brazil – do not consider the focus of the current global emergency and crisis, either transversally or at all educational levels (Salinas et al., 2022). Therefore, if a change in teaching is pursued, a change of vision in the purpose of teaching is necessary; this is a change in the directions or visions of scientific literacy.

Since 2012, many low-income countries that are part of the Organisation for Economic Co-operation and Development (OECD) have been adapting their educational curricula to achieve 'adequate' levels of scientific literacy defined by global standardised tests such as the Program for International Student Assessment (PISA). Some authors consider that students and, in some cases, teachers are not well-equipped with the basic elements of scientific literacy (Cansiz & Cansiz, 2019; Melicherčíková & Tomčík, 2018; She et al., 2019). This adaptation to a standard-based curriculum from other realities could have the effect of 'mimicking' the education systems of one country to be implemented in another without questioning the specific educational context (Hwang et al., 2019). Moreover, this imitative phenomenon might be promoting that teachers appear to be immersed or susceptible in accountability practices, which can affect teachers' autonomy, agency, profession and practice (Guerrero & Torres-Olave, 2022; Holloway & Brass, 2017).

New interconnected concepts are tackling the traditional conceptualisation of scientific literacy since the definitions of the term are continuously evolving because of an increased understanding of the nature of science, sustainability education and citizenship in the 21st century (Chen, 2019), for instance, the intersection of information and science literacy (Klucevsek, 2017); multiliteracies, such as health, political, ecological, financial or emotional literacies; literacy associated with communication and interaction with technologies (Allison & Goldston, 2018); and STEM literacy as an all-inclusive term that includes scientific, technological, engineering and mathematics literacies (Zollman, 2012). Regarding the last approach, STEM literacy which aims "to prepare future workers and citizens for a modern and technological driven society" (Tang & Williams, 2019, p. 7) appears recently to be understood by some as synonymous with scientific literacy (Tang & Williams, 2019), which can be risky since STEM is typically intimately associated with a utilitarian, sometimes neoliberal and instrumentalist basis for global economic growth and productivity (Carter, 2017).

Nevertheless, in the context of the climate crisis, other authors seem to be moving in different directions, presenting new alternatives and from pluralistic visions to the current conceptualisations of scientific literacies towards social and eco-justice (cf. Reiss, 1993), for instance, i) scientific literacy based on controversies and socio-scientific issues, such as routine childhood vaccinations and anthropogenic climate change and socio-scientific issues to help individuals to identify misinformation in everyday life (Drummond & Fischhoff, 2017; Sharon & Baram-Tsabari, 2018); ii) indigenous knowledge to articulate the knowledge acquired through conventional science, which is usually closed and formal with science knowledge from local communities (Kraijitmate et al., 2017); iii) environmental and sustainability literacies which can be considered embedded in scientific literacies specific to environmental education goals (Cohen, 2015; Kinslow, Sadler & Nguyen, 2018; Stibbe, 2009); iv) 'real-world' scientific literacy integrating authentic, multimodal and 'real' scenarios based on field trips (e.g., to natural reserves, health centres, museums, zoos, among others) (Christensen et al., 2015; Buchholz & Gibbons, 2018). These approaches are in tune with scientific and eco-literacies for democratic decision-making (Yacoubian, 2018) and with González et al.'s (2014) approach, which pointed out that scientific literacy is a universal necessity for contributing to social inclusiveness and equality, as well as strengthening the *critical* scientific and environmental literacy of a society to take decisions in an ecological crisis.

However, it is important to examine deeper into the meaning of 'critical' when using this concept, considering the relevance of critical approaches – in the context of a planetary crisis and the urgent call for climate action– to reflect on the world from a transforming and emancipatory perspective that challenges existing hegemony (Hodson, 2011; Valladares, 2021). Roth and Barton (2004) profile a critical scientific literacy that develops in spaces that seek to break hegemony, generating struggles between groups with different power where they emerge from collective practice. When considering these characteristics of scientific literacy, science is shaped as something closer to the reality of its nature: socially built and determined, changing in the face of new evidence and with consequences for societies

(Hodson, 2011; Valladares, 2021). In relation to its teaching, this vision of scientific literacy brought to the school requires a socio-constructivist approach, with the use of methodologies centred on socio-scientific conflicts and transdisciplinarity where different disciplines are integrated to search for solutions, using open questions of local and global relevance (Roth & Barton, 2004; Valladares, 2021). This scientific literacy focuses its implications for teaching to distance themselves from a conventional or functional vision, where learning is individualistic, and the individual does not relate constructively to society (Roth & Barton, 2004). It becomes evident that in this proposal, the critical scientific literacy configuration established points of encounter between science education, politics, economy, environment, citizenship, and even a moral and ethical dimension. This critical approach means a process of conscientisation in science education.

2.3.2 Environmental literacies

Similarly, the concept ‘environmental literacy’ was first introduced by C. E. Roth (1968) in the Massachusetts Audubon Society as a reaction to the frequent media portrayal of individuals who were contributing to pollution and were deemed environmentally illiterate. The initial definition of environmental literacy underwent several revisions as it served as the central concept for the Liberty Council of Schools Environmental Education Projects in the USA, a multi-community education initiative. It was later further developed as a core goal statement for the Massachusetts State Plan for Environmental Education, which was supported by a grant from the National Environmental Education Act in 1972. C. E. Roth (1992) raised the question: ‘How shall we know the environmentally literate citizen?’. Since then, the definition of the term has undergone changes and has been widely examined. To date, multiple studies have claimed that the concepts of environmental literacy or ecological literacy have been applied in various ways, making them overly broad and lacking in specific meaning.

According to Wals et al. (2014), there is a significant degree of similarity between scientific literacy and environmental literacy. To distinguish between them, it is important to have a general understanding of the development and current state of scientific literacy, as outlined in the overview provided above. The two concepts not only overlap, but also have a considerable amount of parallel development. Bybee (1979a) included a significant set of environmental literacy elements in his definition of scientific literacy, stating that:

> the goal of science education should be directed to develop a science literacy that includes the fundamental understanding of the interdependence relationship of individuals with each other (communities) and with their environment. (p. 252)

From the end of the 1980s, different authors claimed that as society evolves and shifts towards a new social and political order, science education requires a different understanding of the goals of scientific literacy (Bybee, 1979b). As a result, science education might gradually adopt an ecological (environmental literacy) standpoint in the policies that shape its programmes and curriculum.

Regarding environmental literacies, multiple studies have argued that – in a similar way as with scientific literacy – the term has been applied in so many different ways and/or is so all-encompassing that it now has very limited meaning (e.g., Roth, 1992; Stables & Bishop, 2001; McBride et al., 2013). Stables and Bishop (2001) argued that the sense of environmental literacy has been deeply muddled due to its uncritical application. Roth (1992) developed an analysis of the evolution of the concept 'of environmental literacy' between 1969 and 1989, seeing an environmentally literate citizen as one who: "recognises environmental problems when they arise. This means acquiring a basic understanding of the fundamental interrelationships among people and the bio-geo-chemical environments" (Roth, 1992, p. 18).

Hart and Nolan (1999) analysed the state of environmental education research during the 1990s, providing critical commentary on its focus and quality, while also suggesting possibilities for improvement in the new millennium. Indeed, in their review, they emphasised the need to address critical, feminist, and postmodern challenges, advocating for deeper qualitative analyses, and fostering collaborations beyond academic settings, particularly with schools and communities. The authors highlighted the distinctiveness of environmental education as a field that extends beyond traditional educational institutions into nonformal or public spheres, distinguishing it from many other areas of educational research. Then, Simmons (1995) examined definitions, frameworks and models of environmental literacy found in 26 sources, including input from individuals, associations, organisations, and state and national guidelines or plans. McBride et al. (2013) then updated the discussion about the necessity to promote awareness of potential environmental issues and understand the connections between human actions and the natural world. This discussion also involves reconsidering critical aspects of environmental literacies and examining the dialogues and the articulation with scientific literacies in recent years from global policies.

In summary, in the new context of sustainability education, scientific and environmental literacies are critical for individuals to understand the environmental, social, and economic impacts of their decisions and actions and make informed choices promoting sustainability. However, studies addressing the concept of scientific or environmental literacy typically do not critically examine the (dis)connection between science, ecology, politics, economics, socio-cultural backgrounds, class, history and, therefore, the distribution of power and wealth (Hodson, 2011). Consequently, conventional approaches to scientific and environmental literacies can be understood as a global standard where knowledge and learning are typically based on an unsustainable, individualistic (neoliberal) ideology that does not take into account the fundamental relationships between the individual and society, knowledge and power (Hodson, 2011). As such, these assumptions are usually framed within a deficit discourse, failing to account for local knowledge, understandings and conceptualisation of what scientific literacy is for, and, as Sammel (2009) argues, "pushing for assimilation of students [and teachers] into Western science ontology" (p. 653), its values and ways of being. To analyse in depth how critical scientific literacies have been conceptualised and understood by researchers in the field, Chapter 3 presents a systematic literature review of scholarly publications in science and environmental education between 1992 and 2022.

In the next section, I propose outdoor science education as a potential didactic and pedagogical scenario that enables a process of conscientisation in science and environmental education, particularly when approached from a local and territorial perspective. By deviating from conventional approaches to scientific and environmental literacies, this educational approach has the potential to enhance learners' understanding of complex environmental issues.

2.3.3 Outdoor science education and scientific literacies

Outdoor science education provides opportunities to learn about ecosystems and the interconnections between living organisms and their environment and can be a powerful tool for developing scientific and environmental literacies and helping students develop the knowledge, skills, and attitudes they need for climate action. This understanding can help students appreciate the complexity and importance of environmental systems and the impact of human activities on these systems (Dillon, 2013; Orr, 2004;). This connection can inspire science educators, teachers and students to care for the natural world and take action to protect it (Rickinson et al., 2004). Outdoor education can help students develop a sense of environmental ethics, including an understanding of the moral and ethical considerations associated with environmental issues (Baker et al., 2019).

In terms of students' learning, science education in contexts other than the classroom can show significant benefits (King & Glackin, 2010). In particular, activities carried out outside the classroom complement pedagogical resources to help students in multiple domains of learning – cognitive, affective, physical and behavioural (Mohamed et al., 2017). It is through contact with 'reality' that students can be helped to relate theory to the practical value of the learning they are building, which can generate meaning and a positive attitude towards the topics addressed in the outdoor activities (Behrendt & Franklin, 2014). Such learning motivates students to develop connections between theoretical concepts seen in classes and what they experience empirically (Falk et al., 1978; Hudak, 2003). Moreover, learning beyond the classroom has been shown to have the capacity to link knowledge to most areas of the curriculum and can be a positive influence on students' understanding, interest and motivation (Braund & Reiss, 2006). Outdoor science education offers opportunities to observe scientific and concepts within specific contexts and usually positively influence inter-social constructs among students (Dillon et al., 2005b; Rickinson et al., 2004). Outdoor science activities connect teaching and learning with students' local contexts (Braund & Reiss, 2005). Specifically, in this thesis, I propose to address student engagement, fostering an understanding of natural and social context around them (Gruenewald, 2003) in meeting students with communities and territories' conflicts through outdoor experiences. This is, therefore, a critical approach of outdoor science education. An extension of this idea and critical theories applied in outdoor education can be seen in Guerrero et al. (2023).

A critical approach for outdoor education is not common in the literature about science education outside the classroom (Patrick, 2023). However, outdoor education seems to develop empathetic relationships with nature, which might be essential to start questioning and connecting social, scientific, political, and economic dimensions to promote environmental responsibility (Bartosh et al., 2010). As a result, different activities developed out of school such as field trips, hiking, camps, and visits to natural reserves can develop students' awareness of and sensitivities to environments through direct personal experiences (Palmberg & Kuru, 2010).

In Chapters 5 and 6, I explore opportunities to promote science outside the classroom based on conscientisation (Freire, 1970), as a first step in promoting collective climate action and questions about links among science, environmental and non-hegemonic sustainability education. Participants in outdoor science activities in local contexts may also view themselves as relevant actors in their communities, as choice- and change-makers, and become part of growing discourses or networks pro-eco-justice. For instance, students and teachers affected by environmental conflicts in their communities should be allowed to deliberate and find solutions to problems by engaging with sustainability principles and values (Cohen et al., 2015). Based on this approach, I propose using socio-environmental conflicts as scenarios in outdoor science activities aiming at reflecting and developing senses of interdependence with nature (Andrade da Silva et al., 2020). According to Temper et al. (2015), a socio-environmental conflict is defined as a dispute involving natural persons, organisations, private companies, and the State, which are publicly communicated (e.g., news articles, protests) and shows discrepancies of opinions. Outdoor education can help develop students' awareness of environmental issues, which are often rooted in scientific principles. Understanding the science behind environmental issues can help students become informed citizens who are better equipped to make decisions (and take action) about issues such as climate change and sustainability.

Thus, outdoor education can be a powerful tool for developing scientific and environmental literacy by providing opportunities to connect with nature, understand ecosystems, and develop environmental ethics. In this thesis, I will explore opportunities to increase teacher's expertise in outdoor education seeking a deep understanding of the interconnected relations between human, non-human and more-than-human entities.

Chapter 3. Critical scientific and environmental literacies: a systematic and critical review

In science and environmental education, the traditional relationship between scientific and environmental literacies has often been described as distant and competitive, based on a predator-prey relationship or that of a host and parasite metaphor (Gough, 2002). Traditionally, science and environmental education have been taught separately with little integration or connection (Gough, 2007; Verma & Dhull, 2017). Science education has primarily focused on scientific knowledge and skills, while environmental education has prioritised attitudes of concern, awareness, and sensitivity in collaboratively solving environmental challenges (EPA, 2021). Furthermore, a perception of competition between science and environmental education has persisted, particularly concerning resource allocation, curriculum time, and institutional support (Wals et al., 2014). This competitive dynamic has manifested in recent years and has also extended to new approaches as climate change and sustainability education.

Science and environmental education fields have strived for recognition and legitimacy within educational systems, leading to potential conflicts and tensions. For instance, even though the foundations of environmental education were initially located in science education, these two areas of learning have grown apart since the 1960s (Gough, 2007). The predatory nature of the relationship refers to the dominance of scientific knowledge and perspectives over environmental knowledge and perspectives. Science has often been regarded as the authoritative and superior source of knowledge, while environmental knowledge and perspectives have been overlooked and occasionally marginalised within science curricula (Birdsall, 2012). The host-parasite metaphor also illustrates a hierarchical relationship between science and environmental education. Science education has frequently been seen as the dominant field, with environmental education viewed as dependent on and subservient to science. Environmental education has often been treated as an add-on or additional component to science education rather than fully integrated and valued in its own right (Disinger, 1987). Nevertheless, according to Dillon (2012) and Wals et al. (2014), given the current climate crisis and socio-environmental challenges, a new symbiotic relationship between both fields might be promoted:

> The complex nature of current sustainability challenges and the need for competent citizens who can adequately respond to them is such that environmental education and

> science education need to develop a mature symbiotic relationship. (Wals et al., 2014, p. 583)

According to Dillon (2012, 2016), science and environmental education need each other to address global issues such as biodiversity loss, poverty and climate change and there should be a new mutualism between the two disciplines. Similarly, some international organisations, such as UNESCO for example, argue for a shift towards an ecological perspective in science education, emphasising the importance of environmental and ecological literacies:

> Environmental learning should be integrated across the science curriculum, with a holistic pedagogy that goes beyond an exclusive cognitive knowledge focus and aims to engage students socially, ecologically, and emotionally in action-oriented learning and participation. (UNESCO, 2021, p. 10)

I strongly agree with Wals et al. (2014) regarding the need to develop a mature, symbiotic relationship between science and environmental education, fostering a transformative movement through a critical and contextually grounded territorial approach, first, because science education is traditionally seen as a neutral and apolitical activity (Bazzul, 2015); secondly, because environmental issues are inherently multidimensional as they relate to interactions between nature, socio-political, socio-economic, socio-cultural, and ethical dimensions in specific territories (Kassas, 2002). Therefore, for Latin American countries, to delve further into the necessity of adopting a critical approach in the evolving symbiotic relationship between science and environmental education within the context of the climate crisis in our region, it is of utmost importance to conduct additional research that explores the existing conflicts and tensions between scientific and environmental literacies, as concepts which are in the core of both fields. Simultaneously, it is imperative to examine critical perspectives to identify potential improvements. This approach will facilitate a more comprehensive understanding of how these two concepts intersect and integrate (Dillon, 2012). Through such examinations, valuable insights can be gained regarding the interconnectedness and interdependence of these literacies, facilitating a critical analysis of their historical and political development.

With these broader objectives in mind, this chapter aims to critically review the perspectives surrounding scientific and environmental literacies since 1992. The chapter will explore the understanding between these two concepts over the past 30 years, while identifying opportunities for integrating and developing a critical and contextualised approach to scientific and environmental literacies, specifically in the context of Latin America. This chapter presents a systematic and critical literature review to examine the range and spectrum of definitions of critical scientific and environmental literacies and to analyse how they have been comprehended, conceptualised, and studied. This critical review aims to provide insights and discuss opportunities for a better understanding of literacies in science education, addressing sustainability challenges and raising awareness of people's cognitive and emotional responses to environmental issues, in the context of a multidimensional planetary crisis.

3.1 Methods

To analyse critical approaches for scientific and environmental literacies, a qualitative and systematic critical literature review was carried out. This process is based on an adapted step-by-step process developed by Bhattacharya et al. (2020), considering the typologies of literature reviews presented by Xiao and Watson (2019) and Barnett-Page and Thomas (2009). This adjusted method entailed five steps: 1) identification of the research questions; 2) systematic search for relevant literature reviews; 3) selection of studies and establishment of inclusion/exclusion criteria; 4) description of selected studies; and 5) definition of processes for extracting information, synthesising data, and discussing the findings.

3.1.1 Identifying the research question

In the light of the research problem outlined in the previous sections, this chapter tries to provide insights into this by addressing the first research question of this thesis:

1. How have critical scientific and environmental literacies been understood in the last three decades, and what are the opportunities for a potential convergence between these concepts?

3.1.2 Systematic relevant literature review search

A pilot search was initiated by a process of exploration in Google Scholar using broad keywords such as 'science/scientific' or 'STEM literacy', followed by the addition of the term 'critical'. This process was subsequently repeated for other keywords, including 'STEAM', 'mathematical', 'chemical', 'physical', 'environmental', 'Anthropocene', and other terms associated with scientific and environmental literacies.

Following the initial title screening conducted in Google Scholar, a systematic search of articles published in various databases was undertaken. With regards to international relevance, a search was performed in the Web of Science (WoS) core collection by Clarivate Analytics, employing keywords such as ‘scien* literacy’ and ‘environm* literacy’, alongside the term ‘critical [keywords] literacy’ connected by the Boolean OR operator. The search was filtered for articles using the Boolean operator AND and was limited to the Education and Educational Research category within the period 1992 to 2022.

This search was supplemented by conducting similar searches in the SCOPUS database from Elsevier and EBSCOhost. Additionally, two Latin American open access databases, SciELO and Redalyc, were included in the search, using terms such as ‘Alfabetización cien*’ AND ‘crítica’, ‘Alfabetización ambient*’, and ‘Alfabetización cien*’ OR ‘ambient*’ AND ‘crítica’.

3.1.3 Selecting studies and development of inclusion/exclusion criteria

The search performed on Web of Science (WoS) using the keyword and Boolean for ‘exact phrase’: ‘critical scien* literacy’ yielded 16 documents. Without using quotation marks, a total of 2,592 documents were found. The search was subsequently refined by utilising the ‘exact phrase’ option for further tests. By employing the Boolean operator AND in separate rows for ‘scien* literacy’ AND ‘critical’, 376 results were obtained, including articles and book sections/chapters, within the ‘All fields’ category. Subsequently, the search was expanded by adding ‘STEM literacy’ AND ‘critical’, resulting in 10 results. However, when searching for the exact phrase ‘critical STEM literacy’, only 1 result was obtained. Similar searches were conducted for ‘Chemi* literacy’ OR ‘critical’ OR ‘Biolo* literacy’ OR ‘Physic* literacy’, yielding 8, 4 and 42 articles respectively. A search for ‘sustainab* literacy’ OR ‘climate change literacy’ OR ‘eco* literacy’ AND ‘critical’ yielded a total of 107 results. Another search using the keywords ‘environmen* literacy’ AND ‘critical’ produced 47 results. In total, 617 documents were located in Web of Science.

The same process was systematically repeated in the SCOPUS (n = 700), SciELO (documents in Spanish) (n = 141), and EBSCOHost (n = 308) databases, resulting in an apparent total of 1,766 documents. However, after eliminating duplicated items using EndNote software and considering all databases, the final number was determined to be 617 documents. From this number, 81 documents were excluded: 33 book chapters, 9 books, 23 conference proceedings, and 9 other documents, as well as 2 PhD theses. After eliminating this last group, duplicated articles, and considering documents until September 2022, a final number of 531 documents was obtained. To define inclusion/exclusion criteria, a careful reading of the abstracts of these 531 documents was undertaken to ascertain their relevance to the research question. The documents were analysed and documented in EndNote software and in an Excel spreadsheet during the preliminary search. Throughout this process, the titles, and abstracts of the 531 documents were reviewed to confirm whether they were connected to empirical or theoretical studies related to critical scientific or environmental literacies. Figure 2 summarises the process of the systematic literature review. The research methods utilised were described in terms of large- or small-scale studies, employing a qualitative, quantitative, or mixed-methods approach. Upon completion of the preliminary review, specific inclusion and exclusion criteria were established. Each article had to meet the following criteria: a) being published in a peer-reviewed journal; b) focusing on critical studies in the science education field or being related to environmental education; c) encompassing studies conducted in formal or informal science classrooms; d) centring on primary or secondary level education; and e) published in English, Portuguese, or Spanish.

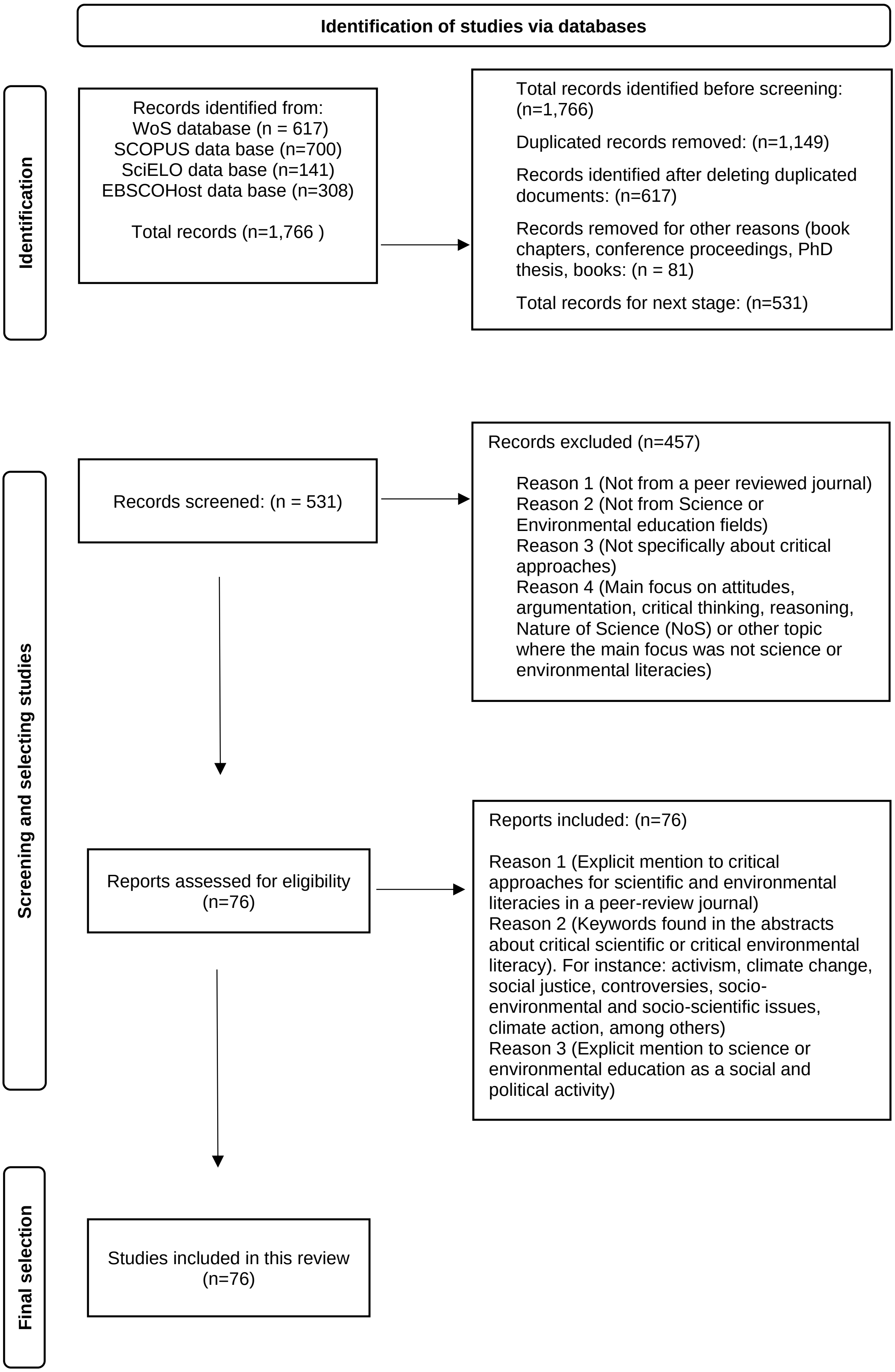

Figure 2. Systematic literature review process and inclusion/exclusion criteria.

3.1.4 Description of selected studies

An iterative process was employed, incorporating the inclusion and exclusion criteria developed during the initial literature search. The first stage involved an overview of all recorded citations. During this process, the abstracts were scrutinised, with an emphasis on identifying critical approaches or connections with political, cultural, ecological, economic, ethical, ideological, social, and other relevant dimensions in connection with critical approaches. The extracted data were documented in an Excel spreadsheet for subsequent analysis.

Final tasks related to the evaluation of quality and acceptability were conducted. Articles that articulated science or environmental education with social, cultural, ethical, political, or environmental issues were identified. Furthermore, preference was given to articles that focused on action-oriented science education, activism, indigenous science or scientific or environmental literacies aiming to foster a more democratic and harmonious society through critical engagement between science, nature, and society. A network of the main concepts found in the literature review is presented in Figure 3.

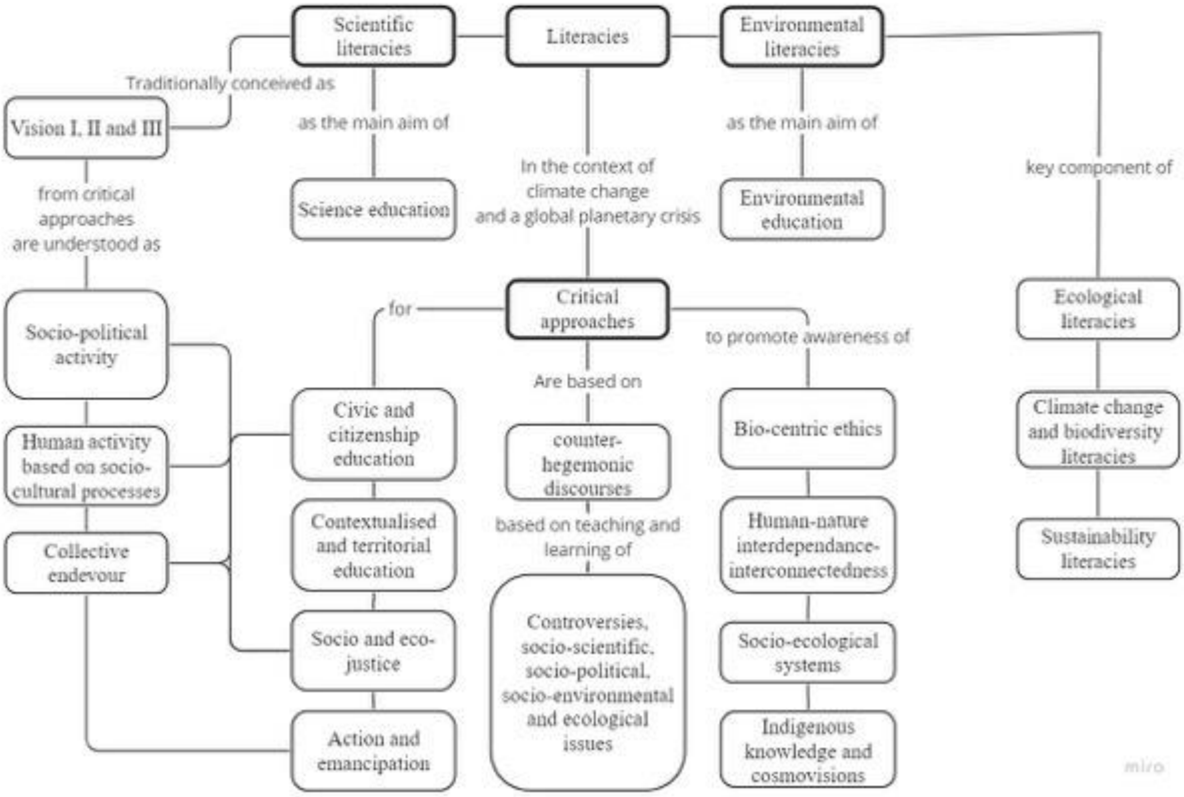

Figure 3. Network of concepts and topics of selected studies based on frequency and inclusion criteria.

3.1.5 Definition of processes of extracting information, synthesis of data and its discussion

The systematic process of identifying and gathering relevant conceptualisations about scientific and environmental literacies was based mainly on utilising specific search terms, keywords, and inclusion/exclusion criteria to ensure the inclusion of relevant documents. This process was developed in an Excel spreadsheet which helped to organise the retrieved information, including bibliographic details of authors, names of journals, main topics and themes of documents, key findings, and relevant excerpts for later analysis.

Then, the process of data analysis and the integration of findings, themes, and key concepts from the selected literature was developed using the software NVivo 14. The software was utilised to identify commonalities, patterns, and gaps within the literature to develop a coherent understanding of the research topic. This software helped categorise and organise the extracted data based on themes, theories or conceptual frameworks, methodologies, and conceptualisation of scientific and environmental literacies. Then this process was exported to an Excel document to facilitate comparison and synthesises. Finally, I decided to summarise and synthesise the main findings and arguments of the reviewed studies over three main time periods to present a comprehensive overview of the existing knowledge decade by decade. The justification for the distribution of the findings in these three periods is based on specific political events and new frameworks developed in the last three decades in science and environmental education:

(1) In 1992, the American Association for the Advancement of Science (AAAS) published a framework for science education entitled *Benchmarks for Science Literacy*. This document outlined the key concepts and skills that students are expected to master in science at different stages of their education.

(2) *The United Nations Conference on Environment and Development,* also known as the *Earth Summit,* took place in Rio de Janeiro, Brazil, in 1992. During this conference, environmental issues were discussed, and Agenda 21, a plan of action, was adopted. This event highlighted the importance of environmental education and its integration into science curricula. Notably, more than 178 governments accepted in Rio the Agenda 21 program for sustainable development worldwide.

(3) During the 1990s, there was an important development of new pedagogical approaches. For instance, the importance of active learning in science education and problem-solving became increasingly emphasised instead of mere memorisation of facts. Additionally,

there was an increased awareness of diversity and equity in science education. During this time, awareness of the lack of diversity in science disciplines grew, leading to efforts to promote the inclusion of students from diverse backgrounds in science education. Moreover, the 1990s was a period of significant advances in educational technology, which allowed for better integration of technology within science teaching.

(4) In 2002, *The World Summit on Sustainable Development*, also known as the *Earth Summit 2002* or Rio+10, was a major international conference held in Johannesburg, South Africa. It was a follow-up to the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro in 1992. The 2002 event resulted in the adoption of the Johannesburg Declaration on Sustainable Development and the Johannesburg Plan of Implementation. These documents outlined the commitments and actions needed to address global challenges and work towards a more sustainable and equitable future.

(5) *Beyond 2000* report: the output of a seminar series organised by the Nuffield Foundation, edited by Jonathan Osborne and Robin Millar. The report argues that the compulsory science curriculum should be designed to develop the scientific literacy of future citizens. *Beyond 2000* in science education refers to the vision and efforts to transform science education from the year 2000.

(6) Large-scale assessments, such as PISA (Program for International Student Assessment). PISA is organised and conducted by the Organisation for Economic Co-operation and Development (OECD). The first PISA assessment was conducted in 2000. PISA assesses the knowledge and skills of 15-year-old students in reading, mathematics, and scientific literacy. TIMSS (Trends in International Mathematics and Science Study), and PIRLS (Progress in International Reading Literacy Study) also started to evaluate elements of literacies. Although, in 2025, it will no longer be a central feature of the new framework, it is relevant to analyse how PISA framed science education in the last decades.

(7) In 2012, the Framework for K-12 Science Education, published by the National Research Council in the United States, served as a foundational guide for the development of the Next Generation Science Standards (NGSS). This approach was globalised to other countries as a reference about what to include or not in science education curricula.

(8) Finally, STEM education and sustainability education started to gain more traction from about 2010.

3.1.6 Limitations

The documents included in this systematic literature review primarily include studies published in 'top' journals. This decision may result in the exclusion of relevant studies and the potential omission of journals not indexed in the databases considered in this study. This exclusion might affect documents written in Spanish and Portuguese, as there may be emerging journals in the field of education that are not yet indexed. Consequently, this limitation can introduce language and cultural bias into the review. Additionally, I acknowledge the subjective nature of the selection and data extraction process. Despite efforts to minimise bias to interpret inclusion and exclusion criteria, the study selection process and data extraction in a systematic literature review inherently involve subjective judgment. However, from my epistemological positionality, it is valuable to recognise that subjectivity is an inherent aspect of qualitative research.

3.2 Initial findings

Some preliminary terms and results of an initial search from Google Scholar are shown in Table 1. The fields of health, science/scientific, mathematical, technological, environmental, ecology/ecological and STEM contained more substantial numbers of articles relating to critical literacy approaches.

Table 1. Initial pilot search with Google Scholar

[Field]	**[Field] literacy**	**Critical [field] literacy**	**% critical**
[none]	4.5 million	66,400	1.47
Science/scientific	73,200/128,000	307/420	0.41/0.32
STEM	4.120	30	0.72
STEAM	420	0	0
Mathematics/mathematical	10,800/27,300	120/427	1.11/1.56
Chemistry/chemical	452/1,290	1/3	0.22/0.23
Biology/biological	212/1,410	0/1	0/0.07
Physical/physics	274/8,650	2/11	0.73/0.13
Geography/geographical	603/794	1/0	0.16/0

Ecology/ecological	138/12,800	1/58	0.72/0.45
Eco/eco-	2,630/6,200	56/10	2.12/0.16
Technology/technological	37,300/44,100	43/294	0.11/0.66
Environment/environmental	1,880/24,200	0/218	0/0.90
Sustainability	3860	3	0.07
Anthropocene	6	0	0
Climate/climate change	3,640/731	1/0	0.02/0
Health	392,000	4,260	1.06
Disciplinary	9,340	50	0.53

Overall, in the last twenty years, most research studies focused on scientific and environmental literacy were published between 2018-2022, followed by those between 2010-2017 and 2002-2009. The search on WOS for scien* literacy returned 2,533 records of peer-reviewed articles but in the case of critical scientific literacy only 13. In SCOPUS, there were 3560 hits for scien* literacy and 19 for critical scien* literacy; for environmental literacy there were 594 but only 4 for critical environm* literacy”. EBSCOhost returned 308 records. Spanish databases returned the following results: for ‘alfabetización’: 14,300 hits and alfabetización científica crítica: 45 hits. A summary of the number of records in the last three decades is presented in Figure 4.

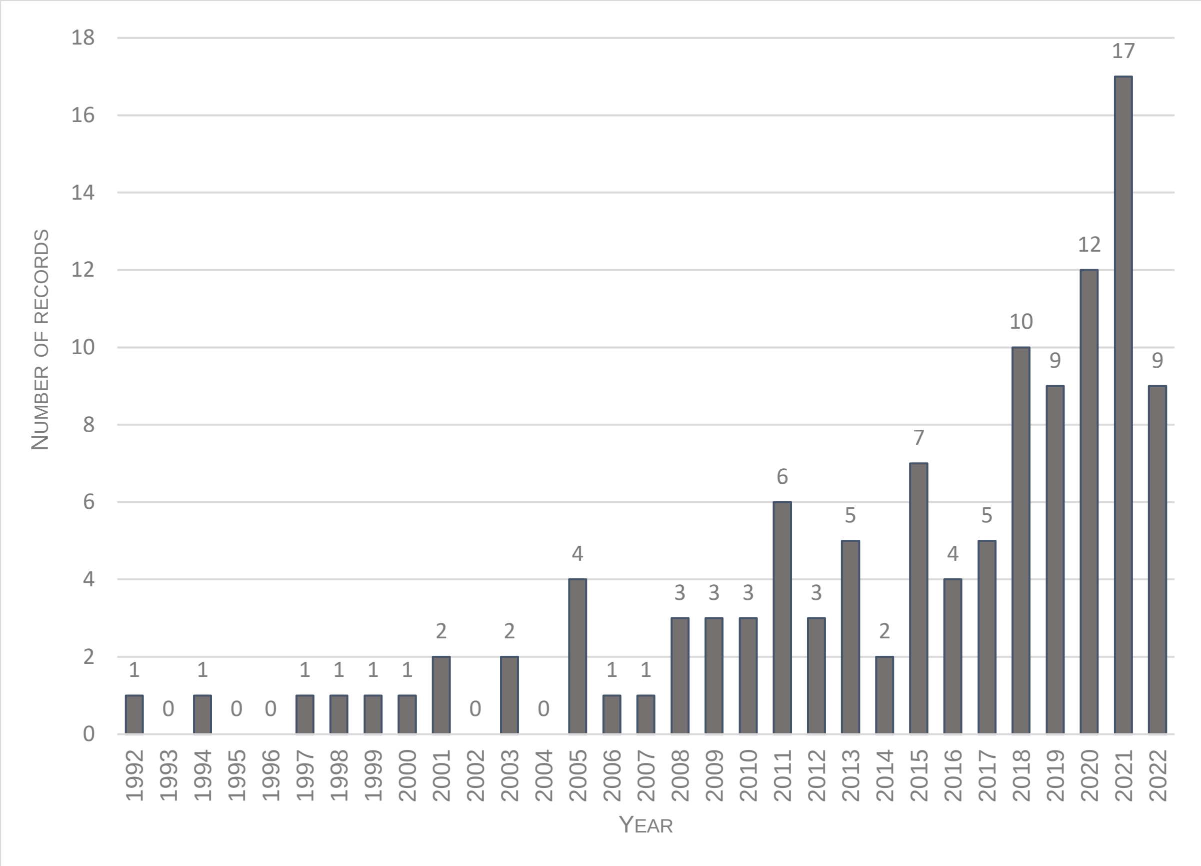

Figure 4. Growth of published papers about critical approaches in science and environmental literacies. Number of papers for 2022 only includes eight months.

3.3 Findings and discussion: Understandings of scientific and environmental literacies from critical approaches

Upon reviewing the literature from 1992 to 2022, it becomes evident there have been various interpretations and understandings of critical scientific and environmental literacies. These concepts have been influenced by political, economic, cultural, ethical, and social factors specific to different contexts worldwide. This section aims to present and discuss the diverse conceptualisations and approaches to both concepts over the past three decades. As discussed, the findings are divided into three main periods. First, the emergence of critical scientific and environmental literacy approaches between 1992 and 2002 is examined. Subsequently, the development and consolidation of definitions and 'new' understandings from 2002 to 2012 is explored and discussed. Prior to moving on to the last decade, a summary is provided of the main authors who have influenced the discussion about critical approaches to literacy in science and environmental education between 1992 and 2012. Finally, the state of the art of the literature and the strengthening of critical approaches between 2012 and 2022 is presented.

Throughout the three last decades, the main topics in which both concepts have been discussed can be summarised in: i) curriculum and science policies; ii) teaching, role of science educators, pedagogy and *didactik* or *didáctica* in the case of Latin American, German or Nordic countries tradition; iii) science in media, public participation, decision-making, and values in science; iv) scientific and environmental literacy and its connection with agency, citizenship and democracy; v) critical environmental literacies for climate change and sustainability education, ecology, health and nutrition, eco-literacies and activisms; vi) socio-scientific issues, socially relevant issues; vii) interdisciplinarity and approaches such as STS, STSE, STEM, STEAM, among other; viii) science outside the classroom and informal science leaning; and ix) decolonial and feminist approaches, such as indigenous science and radical visions of scientific and environmental literacies. Due to the abundance of information for each of the themes, this chapter will only focus on the most significant topics directly related to the thesis and research questions.

References to articles from the systematic literature review sample are indicated using square brackets [], while references to other sources in the literature are enclosed in parentheses ().

3.3.1 The emergence of critical scientific and environmental literacies approaches between 1992 and 2002

In this first period, ten articles were identified. Different ways of understanding and defining critical perspectives in science and environmental literacies were documented. Much of the research conducted during the 1990s on critical scientific and environmental literacies primarily acknowledges the complexity and challenge of defining the concept of literacy, before embarking on a critical examination within the realm of science and environmental education [Bailey et al., 1998]. During this decade, important questions challenged the universal meaning of scientific and environmental literacies. Specifically, there was a focus on interrogating the notion of being a critical science literate citizen and exploring what (in)justices are perpetrated in the name of various conceptualisations of literacies [Bailey et al. 1998]. In general, during this period, there is common agreement regarding the importance of attaining a more comprehensive understanding of significant scientific theories, research methods, and the intricate relationship between science, politics, environment, and society.

This understanding is deemed crucial for the critical evaluation of science and environmental literacies [Mayor, 1992; Schillo, 1996].

Specifically, literature at the beginning of the 1990s starts questioning the assumption of an uncontroversial, apolitical, and unbiased position regarding political matters of science. This might be considered as a starting point to critically examine scientific knowledge and the nature of science in the context of socio-scientific disputes [Bingle & Gaskell, 1994]. For instance, Martin [1992] argued that we need to remember that science is done by human beings who are inevitably influenced by ethical, ideological, and cultural values, and scientists who decide that certain claims should be treated as facts must be influenced by these contextual values. In this sense:

> There is no such thing as a neutral or unbiased assessment of scientific evidence. Rather those assessments that are more persuasive and that seem to others to be more objective are the assessments which are sensitive to the diverse facts of the social context in which science is embedded. (Mayor, 1992, p. 160)

According to Bailey et al. [1998], when viewed through a critical lens, literacy is a multifaceted concept that can be examined from diverse perspectives, including historical, educational, aesthetic, sociological, political, philosophical, cultural, and economic ones. Highlighting the historical context, McBride et al. [2013] emphasise that 'literacy' did not exist until the late 1800s. In fact, according to the Oxford English Dictionary, the word 'literacy' emerged several years after 'illiteracy' (Venezky et al., 1987). Initially, illiteracy was perceived as a concept to distinguish or separate individuals in industrialised societies or 'developed' countries.

The concept of literacy has undoubtedly undergone significant advancements, particularly during the 1990s. During this period, it came to mean more than a mere ability to read and write or possess knowledge and proficiency in specific fields. Instead, it reached a critical threshold where scientific literacy became intricately intertwined with discussions between science, politics and the role of governments [Mayor, 1992]. This defining threshold is exemplified by pressing global environmental issues, underscoring the imperative for international governmental cooperation. UNESCO, for instance, has a relevant role among international organisations in providing invaluable perspectives and extensive operational and research experience to inform the scientific formulation of policy options. According to UNESCO (1979), nationally and internationally, the aim of science policies in education should be to achieve a greater ‘scientification’ of the decision-making process and an expansion of the advisory framework consistent with a recognition of the complexity of science policy issues and of the need for holistic approaches. Notably, a significant institutional link between science and government “was forged during the Second World War, particularly concerning the development of nuclear weapons” [Mayor, 1992, p. 29]. Such historical milestones have laid the groundwork for the subsequent emergence of new understandings of critical approaches to scientific and environmental literacies, evident since the 1990s.

Although establishing a precise relationship between industrialisation and the rise of new understandings of science education poses challenges, compelling correspondences between the two have emerged (Carl, 2009). This alignment is particularly noteworthy in the context of critical approaches, which have arisen in response to political struggles. According to Mayor [1992], recent advancements in various fields, such as communications, physics, genetics, biotechnology, and psychology, resulting from extensive research and experimentation, led to a shift in the way science is understood and have also led to “the need for systematic connections between science, politics and society” (p. 30). Due to the increasingly rapid and diverse relationship between science and industry, and thus the bond between science and society, significant efforts had to be made to increase societal participation and enhance decision-making as a key component of scientific literacy [Bingle & Gaskell, 1994].

In parallel, during the same discussions, doubts about the viability of a global model or agenda of scientific literacy emerged in the early 1990s, particularly when considering environmental problems and the depletion of ‘natural resources’ in specific contexts and territories. Typically, traditional, or hegemonic definitions of literacy collapse when confronted with local territorial realities. This has led to the emergence of critical perspectives and re-conceptualisations that are central to current discussions on what it means to be a literate person in science and environmental education [St. Clair, 2003]. For example, Bingle and Gaskell [1994] pointed out that scientific literacy is often used as a slogan with superficial consensus, because the term holds different meanings for different people. There are different perspectives on how individuals should approach the examination and application of scientific knowledge, and while scientifically literate individuals must make decisions, those decisions are context-specific and linked to specific conflicts and communities, particularly in countries from the Global South. Therefore, according to Bingle and Gaskell [1994], a preliminary meaning of critical scientific literacy is the ability to make informed decisions in the context of socio-scientific or socio-environmental issues through a critical examination of scientific knowledge while also integrating other forms of knowledge (cf. Aikenhead, 1985).

When making a decision in a socio-scientific dispute, it is essential to critically evaluate the scientific knowledge involved, while also considering other forms of knowledge and the values embedded in the different options [Marks et al., 2008]. Aikenhead (1985) and Reiss (1993) emphasise this point by paying attention to the importance of combining scientific knowledge with other forms of knowledge and identifying the values inherent in the alternatives. Besides, in collective decision making there are several social domains impinging upon the decision making: religion, ethics, politics, military issues, among others [Kolstø, 2000, p. 296]. According to Bingle and Gaskell [1994], this critical examination should be taught at school level to accentuate scientific argumentation and to increase scientific literacy for decision-making, raising awareness of the constitutive values in science; and, to examine the potential of knowledge from diverse social domains other than science [Kolstø, 2000]. This perspective enters into tension with what Latour (1987) calls the ready-made-science and science-in-the-making model. In the first one, knowledge is taken for granted and seen as uncontroversial and unrelated to specific contexts of its development. In the second one, scientific knowledge is seen as claims and, therefore, they are contestable and subject to revision and, like any human activity, prone to biases. Kolstø [2000] pointed out that:

> An understanding of the concept of “science-in-the-making” and the role of consensus in science will bring us halfway to meeting a need identified by Osborne (1997) for a science education that seeks to empower young people to act, “The need for students to understand not only ‘what we know’ but ‘how we know’”. (p. 296)

Schillo [1996] discusses a critical approach of teaching animal science and advocates a similar idea, suggesting that a teaching approach based on critical scientific literacy demands a reasonable ‘skepticism’ among students “to facilitate processes to reflect independently and analytically about scientific claims to serve themselves and their communities in responsible ways” [Schillo, 1997, p. 952]. Thus, a critical approach to scientific literacy demands an understanding of the nature of scientific activity and the relationship between science, communities, and the natural world.

Ideas about the natural world, specifically regarding nature in relation to the concept of environmental literacy, are relevant for discussion when reflecting on the purpose of science education. According to Latour's science-in-the-making approach, "Nature has not been defined, and it will be a consequence of the settlement" (Latour, 1987, p. 99). From this standpoint, new discussions have emerged regarding scientific literacy from socio-constructivist and humanistic approaches, acknowledging that science is a human creative activity that reflects the values and biases of its practitioners and is highly influenced by ethics, ideology, culture, and contextual values [Schillo, 1996]. Consequently, a positivist, factual, clinically objective, literal, and absolute vision of science is no longer accepted (cf. Hirsh, 1987). Based on these tensions, a generalisable idea (and standards) of scientific literacy is no longer warranted in science education (Hodson, 1985; Aikenhead, 1985) because science, in the broadest sense, is inherently a form of public knowledge that relies heavily on cultural values and society (Brady & Kumar, 2000).

Thus, the critical scientific literacy approach that emerged during the 1990s emphasised scientific literacy for decision-making with the aim of "increasing the power of citizens to challenge orthodoxy and to participate in decisions affecting their lives" [Bingle & Gaskell, 1994, p. 198]. This approach moves towards a notion of citizen participation in the resolution of socio-scientific disputes or, as Bailey [1998] pointed out, "literacy for social action", or "scientific literacy for citizenship" [Kolstø, 2000]. Science for citizenship, coined in the mid-1990s, is understood as a social process and in the literature is normally discussed as an emergent critical approach of scientific literacy and as an important educational goal in science school curricula. Kolstø [2000], in his article about *scientific literacy for citizenship*, presents a framework for analysing controversial socio-scientific issues or the science dimension of science-related social issues based on science as a social process, limitations of science, values in science and critical attitude. Several authors have pointed to case studies on specific scientific and socio-scientific disputes as arenas for teaching science for citizenship and science as a social enterprise (Reiss, 1993; Jenkins, 1994; Osborne, 1997). This approach will be in the spotlight of science education, and it will be discussed in depth in this review, in the period between 2012 and 2022.

During the 1990s, three metaphors for critical literacies were often discussed in the field: literacy as adaptation, literacy as a state of grace, and literacy as power. Bailey et al. [1998] pointed out that "while literacy is a metaphor, its conceptualisation serves as a slogan and rallying cry for science curriculum reform" (p. 6). Literacy as power has been crucial in understanding the importance of science and environmental literacies from a critical standpoint. The metaphor of literacy as power, which emphasises emancipation and social reconstruction, is somehow linked to resolving societal issues. As I discussed in Chapter 2, this perspective on scientific literacy seems to be in line with the work of Freire and Macedo (1987) on literacy for critical consciousness (*conscientização*). Yet, scientific literacy is a metaphor, and the inclusion of the word 'literacy' in the term makes it particularly powerful as a call to action and to promote social justice. For example, "injustice occurs when a powerful group in a specialised area or in the broad field of literacy perpetuates a narrow view of literacy" [Bailey et al., 1998, p. 10]. Those in positions of power possess the capability to define and set criteria in a manner that excludes specific individuals or groups considered undesirable, thereby reinforcing their own positions and authority. Scientific and environmental literacies are vulnerable to such injustices as they can be subject to criteria for inclusion based on specific achievements or skills. Nevertheless, during the 1990s, as a slogan, the term 'literacy' resists precise definition.

3.3.2 Critical scientific and environmental literacies approach between 2002 and 2012

Between 2002 and 2012, 22 documents were identified. In this period, it can be said that new environmental and scientific literacies approaches contributed radically to changing the way environmental issues were conceived. Specifically, different frameworks for fostering critical environmental literacy in articulation with science education were consolidated. For example, García et al. [2010] argued that we need more and new *didactic* treatments of social environmental issues, such as biodiversity conservation from the double perspective of scientific literacy and environmental education. Similarly, St Clair [2003] discussed critical and active environmental literacies in adults. The arguments in this research reflect a situated and critical way to apply and understand the metaphor of literacy in relation to socio-scientific and environmental issues. The author presents suggestions for a potential portrait of critical and proactive environmental literacy for adults. The concept of literacy is used as a powerful metaphor, greatly aiding in understanding 'what each individual can do to promote a more equitable and sustainable way of life for the global community' (p. 77). St Clair [2003] proposes six dimensions that can lead to critical environmental literacy: i) understanding that all education has an impact on the environment; ii) recognising that ecological issues are complex and cannot be fully addressed by one field or discipline; iii) encouraging education to involve meaningful engagement with the local environment and communities; iv) emphasising that the process of learning is just as crucial as the content; v) including learning experiences in nature as a fundamental aspect; and vi) developing the students' ability to interact with natural systems. In this sense, science and environmental education cannot be accepted as a neutral endeavour made to serve desirable ends; their inherent assumptions about nature and the place of humans must be re-evaluated.

The importance of recognising environmental literacy as a human and social concern is reflected in Potter [2009] and in a report of a research project setting out to identify the social science concepts necessary to understand environmental issues [McKeown-Ice & Dendinger, 2000]. For instance, individuals engaged in efforts to reduce the use of polluting personal transportation in their local area do not necessarily need to possess detailed knowledge of molecules or chemistry. Studying the environment is not all about science [Chepesiuk, 2007]. It is more practical to start with the essential knowledge that is most relevant to the 'real-life' problem, such as understanding pollution in relation to health. This does not imply that scientific knowledge is trivial, but rather that it is just one resource for taking action, alongside personal experiences, ethical considerations, political or economic interests, and other significant concerns. According to St. Clair [2003], adults are typically more motivated to learn and act when they are invested in issues that they care about and experience every day rather than abstract concerns. Therefore, a critical role of educators is to demonstrate to people why they should care about the environment from a territorial or contextualised perspective, before expecting them to acknowledge its importance and begin to develop environmental literacy from pure scientific content [Chepesiuk, 2007]. In this sense, it is relevant to consider people's understanding of science and nature might be inevitably influenced by factors such as gender, ethnicity, religious background, socioeconomic status, geographical location, and so forth. Moreover, educators who are passionate about promoting environmental literacy must ensure that their work is connected to and contributes to local, national, and global social movements dedicated to addressing environmental issues [Chepesiuk, 2007].

In the first decade of the 2000s, different perspectives on critical scientific literacies progressed. This movement can be attributed, in part, to the aftermath of the report *Beyond 2000* in which a group of influential scholars in Western science education convened to assess the future of the science curriculum (Millar & Osborne, 1998; Reiss et al., 1999). Simultaneously, the United States made efforts to establish a comprehensive science curriculum, as evidenced by the publication of the report *Inquiry and the National science education standards* (National Research Council, 2000). However, according to Donnelly

[2005], both reports sparked controversy because they only differentiated between a small segment of the population referred to as ‘future scientists’, for whom science holds direct occupational relevance, and the remainder referred to as ‘lay people’, who are not professionals or experts in a particular field, in this case science. For this latter group, the importance of science stems from the increasing relevance of scientific matters in their everyday existence and the necessity to engage with science and its discussions attentively (Millar & Osborne, 1998). To tackle this situation, Dillon [2009] pointed out “we have to find ways to work with the term and then find ways to disrupt the hegemony that it holds over curriculum reform and assessment regimes” (p. 211). Donnelly [2005] suggested reforming science in the school curriculum to incorporate a range of scientific literacies, including social, political, legal, financial, parental, health, environmental, and emotional literacies. Emotional literacy emerged as a key component of critical scientific literacy during this period, as highlighted by the work of Matthews [2002, 2004]. Regarding emotions, different contemporary authors still discuss the necessity of including emotional literacy, outlining potential pathways for science and environmental education which focus on the social and emotional development of students:

> We must take into consideration the relationship between the development of science, technology, and politics, creating a state of mind in students that fosters emotional development such as inclusion, tolerance, collaboration, empathy – aiming for the common good. [Galamba & Matthews, 2021, p. 585]

Supporting new potential pathways, Donnelly [2005] called for a radical revision of the fundamental aims and purposes of science education and discusses critical dimensions of science literacy since ‘the notion of the concept has been left mainly unexamined within contemporary curriculum’ (p. 301). Donnelly [2005] suggests addressing three key issues:

(i) the importance of science, specifically its philosophical and socio-political aspects, in modern life and decision-making, both individually and collectively
(ii) the effects of proposed curriculum changes on the appeal of studying science among students, both before and after mandatory education
(iii) the relationship between all these factors and the supposed separation between pre-professional science education and a general education that includes science.

In this period, the conceptualisation of scientific literacy tried (with great success) to be globalised and exported to different contexts. As a consequence, a hegemonic conceptualisation was developed by policymakers and science education experts, mainly from Global North, prioritising preparing and evaluating students for a technologically advanced, urban, competitive, and globally oriented economy. Additionally, the emphasis on performance-based standardised national and international exams such as the Trends in International Mathematics and Science Study (TIMMS) were key factors in the development of hegemonic and Western-based approaches to scientific literacies [Chinn, 2007]. Paradoxically and ironically, the absence of relevant local science or the recognition of indigenous knowledge in local curricula paved the way for decolonial perspectives in science education and critical approaches to both scientific and environmental literacies. Consequently, scientific and environmental literacies between 2002 and 2012 seem to have deepened a confrontation between dominant/hegemonic and marginalised cultures.

When a science curriculum is established by considerations that are not specific to a community, particularly those of minority or indigenous groups, the teaching of science tends to disconnect from students' experiences, local scientific issues, and traditional ecological knowledge [Kawagley et al., 1998; Snively & Corsiglia, 2001; Reid et al., 2002]. An example of this is demonstrated by Chinn [2007] through the marginalisation of indigenous/traditional/ local knowledge in Hawaiian schools due to the imposition of the Western Modern Science ideology:

> Hawaii's students have a unique natural laboratory to explore fundamental biological questions involving evolution, adaptation, and interactions of humans and the environment on isolated island systems. But most learn classroom and text-based science, perhaps becoming literate in school science but not issues relevant to their own lives and communities. Thus, Hawaii's teachers, especially those in elementary programs that require only two semesters of science, are unlikely in either their K–12 or college years to gain the science knowledge and tools to integrate their own and their future students' familiar environments into their teaching. [p. 1248]

Examples from Hawaii are also valuable when discussing the conceptualisation of critical environmental literacy. In Hawaiian culture – as in many indigenous communities in Latin America and diverse contexts in the Global South – humans are considered as part of nature in which plants, animals, and non- or more-than-human entities possess ancestral and spiritual significance. Chinn [2007] presented decolonial methodologies for professional development considering critical and non-hegemonic literacies based on indigenous knowledge. This radical approach demands a critical analysis of curriculum and pedagogy by science educators. In this approach, science teachers developed their lessons based on transformative learning, incorporating active learning in situated contexts to develop a sense of place and connection with nature. This model recognises the importance of biodiversity, builds social networks, understands power knowledge relationships, learns from elders, and uses traditional places to protect and respect ancestral culture and knowledge [Hall, 2004]. This model of professional development suggests the potential of decolonial and critical methodologies to incorporate and increase local science knowledge and teacher agency, and knowledge diversity in science and the participation of underrepresented minorities [Chinn, 2007]. In doing so, science teachers might develop tools to allocate learning in students' lives to promote a critical scientifically and environmentally literate society which recognises powerful interests behind globalisation, exploitation of 'natural resources', national curricula, and marginalisation of indigenous communities. Complementarily, this might be also an opportunity to reconnect Western modern science to culture, place, and community.

Western scientific methods of acquiring knowledge, such as measuring, classifying, collecting, dissecting, and mapping everything in an observable, physical world, are in opposition to some African or Hawaiian perspectives which see humans and nature as part of a whole or part as a family [Ramsuran, 2005]:

> science is often seen as offering useful but limited view, in that it ignores the reality of spiritual life and spirit forces and too readily sets aside context, continuity and collectivity in favour of objectivity and reductionism. [Ramsuran, 2005, p. 2]

In this sense, there is an ontological, epistemological, and axiological conflict at the moment of defining a model or visions of scientific literacies. Axiology deals with values, ethics, and aesthetics, ranging from values *in* science (objectivity and elegance) to the values *of* science (what science is for). Reiss (1999) pointed out that ethics and science education are inevitable and inexorable conflated. In terms of ontology and epistemology, science policies about scientific literacy are strongly ideological and normally in tension between localisation and globalisation, Western (Universal) or local science and individualistic and collectivist approaches. Ramsuran [2005] made a call for the *Africanisation* of scientific and environmental literacies. This idea can shed some light and provide opportunities to promote a *Latin-Americanisation* of science and environmental education, based on a social reconstructive ideology, on equity, transformation, multiculturalism and multiethnicity, and the professionalisation of teachers as professionals who can contribute to the development of public policies and curriculum design, understanding science and environmental literacy as a collective endeavour.

Ramsuran [2005] utilises the idea of ideology to analyse philosophical and sociological interpretations of scientific literacy aims and possible effects in society. According to Gramsci (1971), ideology can be described as a ‘terrain’ consisting of practices, principles, and dogmas that have a material and institutional nature. This terrain encompasses individuals once they become part of it within a particular hegemonic system. The dominant class holds state power due to its economic supremacy and its ability to effectively articulate the essential elements of prevailing ideological discourses among the subordinate classes in society. Gramsci (1971) referred to the social actors he called ‘organic intellectuals’ who belong to a hegemonic or potentially hegemonic class. These organic intellectuals have the dynamic role of articulation, giving rise to an ‘organic ideology’. This ideology is constructed through an ‘articulating principle’ that brings together diverse ideological elements from the discourses of subordinate groups (classes and individuals) and shapes them into a coherent ideological system that becomes the ‘hegemonic principle’. The ontological, epistemological, and axiological principles rooted in hegemonic ideologies are evident in science curricula, reflecting interests and values of the dominant class (Norambuena et al., 2023). These principles might shape and define a specific approach to literacy within the curriculum, serving as a manifestation of the hegemonic ideology prevailing in a specific political and economic context.

Ramsuran [2005] discusses scientific literacy and the concept of ‘ideology’ in the natural science curriculum in Africa, based on the impact of the apartheid state and its influence on curriculum policies. According to the author, pre-1994, those policies can be described as racist, euro-centric, sexist, authoritarian, prescriptive, unchanged, context-blind, and discriminatory (p. 1). However, in 1997, the Minister of Education in South Africa launched Curriculum 2005 (C2005), which represented a profound shift in the science curriculum and, therefore, in the understanding of science literacy. The author questioned the term ‘scientific literacy’ and the relevance of its conceptualisation in countries in Africa, and in countries with issues of poverty, language, and remarkable inequities. In this sense, relevant criticism starts to mark the new understanding of literacies in the 2000s from Global South scholars.

Some questions that arise in this period that are relevant to highlight are: 1) Does the use of the term ‘scientific literacy’ in many different countries imply universal agreement on what is deemed most valuable to learn in science, and if so, why? 2) In what ways does the universalised definition itself serve as a political strategy, promoted by specific groups and for specific reasons, and supported by standardised tests and textbooks? In this regard, scholars from Africa raise a question that is also relevant for Latin America: to what extent is it appropriate for South Africa to adopt such definitions? The process of hegemonisation and the hegemonic conceptions of scientific literacy need to be critically examined, not only in terms of the content, skills, values, and language included, but also in terms of whose knowledge it represents and why (Guerrero et al., 2024). Similarly, experiences from Māori culture and Kenyan teachers describe projects to recognise and respect culture of indigenous people by rethinking scientific and environmental literacy based on decolonial methods to challenge dominant perspectives in science education [Gitari, 2006]. Incorporating indigenous knowledge and science education in students' lives and environments helps to create a society that is knowledgeable in science and environmentally aware in a rapidly changing and interconnected world [Chinn, 2007]. According to different science educators working with decolonial methods, including indigenous knowledge within the school science curriculum can provide an ethical and holistic perspective on ecosystems (Gandolfi, 2021; Kato et al., 2023). However, this process of recognition implies awareness of how power-knowledge contexts are shaping school science knowledge.

According to Bang et al. (2018), science educators and policy makers should recognise how indigenous and Western systems differ, but also how indigenous science constitutes an important accompaniment to the dominant paradigm of Western science that may be vital in addressing contemporary problems related to climate change and sustainability. However, and according to Chinn et al. [2008], there are distinct differences in the goals, intellectual focus, association with human actions, perception of time, validation criteria, and general perspectives between indigenous knowledge and Western science. Indigenous knowledge prioritises survival and harmony with nature, while Western science often seeks knowledge for economic gain and power over nature. Indigenous knowledge also values coexisting with the mystery of nature and is intimately and subjectively related to human actions, while Western science aims to eradicate mystery and is formally and objectively disconnected from human actions [Ogawa, 2004]. Indigenous knowledge is also viewed as holistic, intuitive, and spiritual wisdom, while Western science is often reductionistic, manipulative, and mechanistic in its explanations:

> It is important to be aware of and take into account both the similarities and differences between indigenous knowledge and Western science when creating educational experiences about nature and natural events that are culturally sensitive and respectful. This can lead to an increase in science literacy and provide opportunities for all students to reach this goal. [Ogawa, 2004, p. 586]

Chinn et al. [2008] suggest that Western and indigenous science should be viewed as parallel forms of knowledge. In this sense neither of them is superior to the other. However, we should recognise that the ontological foundations of scientific explanations differ amongst the various knowledge systems about nature and naturally occurring events (p. 157). In the same vein, Reiss (1993) argued that both Western and indigenous science are forms of ethnoscience. Western sciences might be considered as indigenous to the West. Calling for science education for a pluralistic society, he pointed out that:

> We should not assume that within a particular society, all scientific thinking operates within the same paradigm. By virtue of differences between individuals in such important characteristics as gender, religious beliefs (or cosmovision), ethnicity, class, age and disability, individuals may differ in their scientific understandings and conceptions of the world. (p. 25)

Given this notion, science educators and science policy developers should consider diverse ways of understanding scientific and environmental literacies. Embracing the concept of multi-literacy in science and ecology also entails reflecting on the development and transmission of traditional knowledge systems [Stephens, 2000]. For example, trust in wisdom, which is not inherent in Western scientific reasoning, and the incorporation of local verification or ecological knowledge derived from oral traditions and storytelling could be significant points of discussion when considering critical approaches to literacy. In the same vein, numerous authors have reflected on how knowledge construction and technological innovation are often propelled by dominant elites (Gould, 1993). Consequently, Western science, being a cultural endeavour, frequently confers second-class status or insufficient recognition on individuals from non-mainstream cultures.

In the last period of the decade between 2002 and 2012, some authors also question the aims of environmental literacies and the role of governments. For instance, Potter [2009] recognises that environmental literacy is fundamental to address economic, social, and ecological problems that are having a profound impact on us as present and future inhabitants of this planet. In this task, federal governments play a critical role in educating everyone about the environment:

> To develop an environmentally literate society – that is, to build national capacity to develop and deliver high quality EE programs and materials – is going to require massive investment every year from now on into the foreseeable future. (p. 31)

This also means raising awareness of nature deficit disorder and, for instance, the disconnection of children and adults from nature (Louv, 2008).

From reviewing the literature from Latin America, there is a big influence of Paulo Freire on definitions and understandings of the meanings of critical scientific and environmental literacy. For instance, Santos [2006] pointed out a humanistic proposal for scientific literacy in chemistry education. The author reflects on globalisation and political action in a similar way to Marks et al. [2008]. Both these publications make a call to support political action aimed at improving the quality of life and protecting the environment through sustainable development, based on social inclusion. They advocated a socio-critical and problem-oriented approach to chemistry lessons. In Santos' proposal, the ideas of Freire regarding literacy are deemed relevant for promoting a critical scientific literacy approach that fosters conscientisation through the problematisation of social issues. Santos [2006] raises questions about "the terrorism perpetrated by foreign countries invading the Global South and the responsibility to promote an approach to scientific and environmental literacy that engages students in such discussions" (p. 619).

3.3.3 Brief summary of influential scholars between 1992–2012 in the development of critical approaches in scientific and environmental literacies

Most of the studies in critical scientific literacy between 1992 and 2012 – in the Global North – are based on five main approaches developed by Wolff-Michael Roth, Angela Calabrese Barton, Glen Aikenhead, Michael Reiss, and Derek Hodson. In the case of critical approaches for environmental literacies, the main approach is based on Charles Roth and David Orr. The latter is mainly from a theory of ecological literacy (Orr, 1989).

W.-M. Roth and Barton (2004) argued that critical scientific literacy emerges in situated struggles over socio-scientific issues. In doing so, they argued against the decontextualised and self-referential knowledge that science education provides in schools. In addition, a more radical or critical view of scientific literacy is a process in which communities are actively involved in collective praxes. In this reconfiguration of roles, 'collectives' play important roles in making decisions on the issues within the local context and as such provide the focus for what students will learn. W.-M. Roth & Barton [2004] pointed out that not everybody needs to have the same basic sets of concepts and skills; rather, it is more important 'to allow the emergence literacy as a "collective property" or as a collective scientific literacy' (p. 263).

Those who use Aikenhead's (1985, 2007) work as a reference to develop the ideas of critical scientific literacy include Bingle & Gaskell, [1994], Kolstø [2001], Chinn [2007], Chinn et al. [2008], Weinstein [2010] and Choi et al. [2011]. Aikenhead asks what counts as scientific literacy in different contexts. Based on Roberts (2007) and his heuristic framework to understand ideologies of scientific literacy, Aikenhead (2007) argued that *vision I* and *vision II* (discussed in Chapter 2) are mutually exclusive in science classrooms and the combination of both is detrimental for students. However, according to Aikenhead (2007), science educators must address political realities because research, policy and practice are traditionally driven by politics and its internal dimensions: elitism, privilege, funding, allegiances, among others. Indeed, according to Aikenhead (2007), the movement between *vision I* and *vision II* is a political movement. Similar claims have been strongly contested in recent years by a few authors understanding scientific literacy as a political event and a political discourse [e.g., Guerrero & Torres-Olave, 2022; Roberts, 2007]. I also agreed on the meaning and conceptualisation of environmental literacy as a highly problematic and contested concept, especially on political grounds.

Research evidence on critical literacies from various authors between 1992 and 2012 demonstrates the imperative of broadening the scope of scientific and environmental literacies. This expansion should focus on political aspects (Orr, 1989; Aikenhead, 2007), as well as acknowledge the challenges associated with sustaining new alternative approaches in scientific and environmental literacies. This awareness is crucial, as critical perspectives can either be marginalised or co-opted by prevailing hegemonic ideologies.

Furthermore, most studies aligned with Reiss (1993) advocate for a more equitable science education that incorporates three essential categories: multiculturalism, anti-racism, and feminism in science education. Similarly, Hodson (2010) emphasised that educators and students should cultivate a profound commitment to anti-discriminatory practices in science education, with a strong commitment to unveiling the shared underpinnings of sexism, racism, homophobia, Eurocentrism, and Westism (or Northism) in the propensity to create dichotomies. These previous considerations are especially pertinent when examining the perspectives of numerous indigenous cultures worldwide. In the case of Latin America, these indigenous cultures have developed distinctive ways of interpreting the world and forging a profound connection with nature through empirical, spiritual, and rational avenues. Thus, critically scrutinising the conceptualisation of scientific and environmental literacies entails acknowledging that traditional viewpoints often confine themselves to Eurocentric science, disregarding other scientific worldviews [McKinley, 2007]. Moreover, this scrutiny underscores the importance of recognising and preserving diverse ways of comprehending the essence of scientific and environmental literacy. As a conclusion, a significant portion of the discourse within this period aligns with Derek Hodson's core concept of critical scientific literacies:

> Critical scientific literacy involves recognising how science and technology can disproportionately benefit the wealthy and powerful, often at the expense of the well-being and interests of marginalised communities. This dynamic can perpetuate existing inequalities and injustices. (Hodson, 2010, p. 200)

3.3.4 Where are we now? Critical literacies between 2012 and 2022 in the context of the climate crisis

In this final period, from 2012 to 2022, 43 articles were identified. Due to the massive body of literature and acknowledging the complexity of summarising the number of documents, the synthesis of the main findings are presented in three main parts: i) Critical eco- and environmental literacies and new understanding of living things; ii) Outdoor science and environmental education in the promotion of critical literacies; and iii) Climate change education and critical scientific and environmental literacies.

3.3.4 Critical eco- and environmental literacies, new understandings of living things and climate justice literacies

Between 2012 and 2022, the growing concern for ecological issues and curricular changes in the educational system favoured the progressive inclusion and revision of the components of environmental literacy in schools. In recent literature Kaya and Elster [2019], redefined the concept of environmental literacy to contribute to training more qualified environmentally literate people to protect and improve the environment as a fundamental part of human well-being.

Kaya and Elster [2019] considered experts' opinions (scientists, educators, and environmental educators responsible for environmental education) to revise the concepts that need to be included in the definition of environmental literacy. As a result, the authors suggest adding seven 'new' dimensions: knowledge and understanding of environmental issues; environmental attitudes; environmental motivation; morals and ethics related to the environment; intention to act in an environmentally friendly manner; environmentally friendly behaviours; and sustainability. In the same vein, from Mexico, Sánchez [2015], pointed out the addition of critical ecological literacy as a new pedagogy for the understanding of living beings. He suggests considering critical dimensions of awareness in environmental literacy:

(i) Interdependence among all the members of an ecological community, as they are interconnected in a vast and complex network of relationships, the web of life.

(ii) The cyclical nature of ecological processes, as feedback loops are pathways through which nutrients are continuously recycled. This implies understanding that entire communities of organisms have evolved this way over billions of years, endlessly using and recycling the same mineral, water, and air molecules.

(iii) Cyclical exchanges of energy and resources in an ecosystem are sustained in an omnipresent cooperation, that is, by establishing links of entities living within each other and cooperating.

Both Sánchez [2015] and Kaya and Elster [2019] argued for different key aspects to achieve maximum sustainability. Similarly, in the decade beginning in 2000, eight papers have discussed new labels for critical approaches to environmental education, specifically intertwined with the concept of ecological literacy. According to Sánchez [2015] and Pitman et al. [2018], ecological literacy represents a novel educational approach to be introduced or infused by science and environmental education curricula, focused on comprehending living beings and their ecological context.

Ecological literacy involves understanding how plants and animals (including humans) depend upon each other, how populations evolve, how biotic and abiotic elements interact with each other, and how systems work together to create energy and cycle materials; it forms the foundational knowledge required by the human species (Capra, 1996; Capra & Y Luisi, 2014). It can be acquired and communicated in as many ways as humans learn and pass on learning, including through direct observation, teaching, or storytelling [Pitman et al., 2018, p. 118]. Ecological literacy offers a perspective of life as a totality (a complex) in which humans have an inescapable role through our interdependent relationships with non-human (or more- than-human) entities, surpassing narrow and outdated views to make way for the optimism of action. Thus, ecological literacy is a critical factor in achieving sustainability [Capra & Stone, 2010]. In the words of Pitman et al. [2018]:

> Our inherent relationship with natural systems means, in effect, that we are part of nature, despite the authority our species has so often attempted to wield over nature. A disturbing aspect of the rapid change we are experiencing on Earth is a disconnection between much of humanity and the natural world in ways that threaten our sustainability. (p. 117)

Nevertheless, ecological literacy extends beyond just academic knowledge; it also encompasses emotional, social, and ecological intelligence [Sánchez, 2015]. Pascuas Rengifo et al. [2020], affirm that educational institutions must adapt so that students mobilise emotional relationships with nature from the beginning of their school education. In this sense, by nurturing these forms of intelligence, critical ecological literacy cultivates a sense of responsibility and a deep connection with nature.

However, current teaching practices often fall short in providing a profound understanding of ecological processes, merely touching on surface-level aspects. For instance, Pérez-Martín and Bravo-Torija, [2018] suggest that science teacher education programs in environmental education are traditionally focused on the presentation of traditional or non-controversial environmental issues, such as recycling. In this sense, the ecological approach within environmental literacy might be superficial and disconnected from local socio-scientific and socio-environmental issues for students. This inadequacy stems at least in part from the challenge faced by teachers who must incorporate topics that were not part of their academic training at university. To address this, Sanchez [2015] and Kinslow et al. [2019] emphasise the importance of a paradigm shift in the philosophy of teacher education, re-evaluating curricula, embracing project-based learning in ecological education, and emphasising experiential learning and direct engagement with the environment. This shift aims to uncover any significant relationships between ecological literacy and the value people placed on nature, the amount of time spent outdoors and in contact with nature, and the perceived sources of knowledge and understanding [Pitman et al., 2018].

According to Pascuas Rengifo et al. [2020], an eco-literate individual must understand and know the place where they are, the ecosystems that make it up, the ecological principles that govern it, and their global and local connections from a systemic approach [Pitman et al., 2018]. According to Pérez-Martín & Bravo-Torija [2018], to comply with these principles, we also need education for environmental justice; likewise, we need environmental education framed within a paradigm of complexity (Bonil et al., 2010). This framework should consider an integral perspective (social, ethical, economic, ecological, scientific, environmental, etc.) and the distribution of content, in a collective reflection – at least in the short term – in awakening environmental awareness. In doing so, educators can foster more effective and a deep ecological education.

Deep Ecology emerges as a prominent concept, from its earlier roots, advocating for profound ecological awareness and the seamless integration of critical environmental literacy practices into education. According to Sánchez [2015], the principles of Deep Ecological Literacy aim "to promote a profound change in the common conception about the Earth and living systems, fostering place-based learning that looks towards the future and the coming generations" (p. 381). Deep ecology is a biocentric challenge in education, aiming to protect nature by producing through conservation and conserving through production, as proposed by sustainable development, balanced and in harmony with the environment [Sánchez, 2015]. Expecting to play a critical role in raising environmental literacy among school learners, this framework might be a new alternative to recognise the importance, implication, and limits of the systems of the web of life and a critical approach within environmental literacies. According to Sánchez [2014], this is an unavoidable option for the survival and quality of life of all ecosystems, of which human beings are just one element.

3.3.6 Outdoor science and environmental education in the promotion of critical literacies

Over the decade from 2012, diverse empirical methods for advancing critical scientific and environmental education approaches have emerged. Specifically, in this section I present an analysis of opportunities and challenges drawn from articles that explore how outdoor education experiences can potentially facilitate and enhance critical scientific or environmental literacies.

As previously mentioned, teaching and learning outside the classroom have been portrayed in the literature in science or environmental education with a wide range of labels, including situated learning, informal education, outdoor learning, fieldwork/study, field-based learning, learning in natural environments, and experiential education, among others. In this section, I will employ the concept of outdoor science and environmental education to simplify the spectrum of definitions. In the case of outdoor science and environmental education, the notion of unfinished science (Latour, 1987), as a theoretical framework, gained momentum in the last 10 years. Unfinished science is an umbrella term that involves various designations and subcategories, including science-in-the-making (Latour, 1987) and Public Understanding of Science (Lewenstein & Bonney, 2004). The idea of 'finished' science as a 'polished, objectified, linear, and persuasive story' Bucchi (1998), is criticised by many scholars. For instance, Hine and Medvecky [2015] and Navas and Pedretti [2022] present progressive views of critical scientific literacies in the context of teaching and learning science in museums. Learning in those places is normally not rigidly planned or limited by the educational goals of science curricula. Therefore, creating an open learning environment can alleviate the pressure on both students and teachers to achieve specific learning outcomes and assessments, which is often experienced in traditional school settings.

Museums and other extracurricular places, by presenting innovative information and exploring the social and cultural aspects of science and technology across various historical periods and locations, frequently offer open-ended activities resembling the idea of unfinished science scenarios. Museums are increasingly recognising their significance as key participants in various scientific, social, cultural, and political realms, acknowledging that the dissemination of scientific knowledge involves a pedagogical challenge influenced by public literacy beliefs [Hine & Medvecky, 2015]. Transcending the idea of simply being temples or collections houses, science museums are now increasingly being urged to transform into spaces for public discussions and settings where critical and civic scientific literacy can be nurtured, equipping citizens for sustainable futures. In this vein, Navas and Pedretti [2022] draw attention to various museum exhibitions that showcase climate change (e.g., KlimaX – The Norwegian National Museum of Science, Technology, and Medicine), biodiversity loss (e.g., Schad Gallery: Life in Crises, Royal Ontario Museum), and food consumption (e.g., *Comer: Las mesas de América Latina* [Eating: Dining rooms in Latin America], Parque Explora). These examples illustrate how museums are adapting their landscapes and exhibition practices over time.

From a Freirean perspective, Marques and Marandino [2018] point out that this shift in the hegemonic and sometimes elitist idea of what a museum should be is relevant to open a dialogue between experiential and scientific culture, the appropriation of knowledge (related to the nature of science (NOS), and science, technology, society, and environment (STSE) perspectives), and social participation (involving decision-making and social transformation). According to Hine and Medvecky [2015], as institutions of authority, "museums not only present information about science but also shape the way society perceives science as an activity and scientists as a community" (p. 10). Navas and Pedretti [2022] argue that museums play a crucial role in comprehending the dynamic nature of scientific discovery, enabling programs to achieve genuine and widespread public engagement and political influence. They provide an opportunity to present the complexity of science, including its social and philosophical aspects, thereby fostering what can be termed 'critical' in science literacy. As a result, museums, and science centres or national parks, serving as platforms for outdoor science and environmental education, have become essential resources for supporting both young and adult education and are regarded as key institutions, advocating for a broader understanding of the culture of science, falling potentially under the umbrella term of critical science and environment literacy scenarios. For instance, in the words of Hine and Medvecky [2015]:

> Critical science literacies increase the awareness and knowledge of 'how science works', of the sociological and philosophical underpinnings of scientific processes, then unfinished science ought to feature much more prominently in our science communication institutions, such as museums or science centres. [p. 9]

Alongside the development of literacies in outdoor science and environmental education, critical science literacy has evolved into a concept that emphasises enhancing individuals' ability to comprehend, evaluate, assess, and interpret science and scientific statements, rather than merely increasing their knowledge of scientific facts or claims. In essence, critical science literacy is centred around the development of skills, focusing on epistemic capacity rather than epistemic content [Hine & Medvecky, 2015].

Nevertheless, despite the vast evidence that valuable learning can take place in out-of-school contexts (Dillon et al., 2005a; Falk & Dierking, 2000; Guerrero & Reiss, 2020; Rickinson et al., 2004), the literature reports three main challenges in promoting a critical approach within outdoor science and environmental education. The first concern is how to foster inter-institutional dialogue between informal and formal institutions to enhance learning and promote scientific and environmental literacy for future societies [Kim & Dopico, 2016]. According to Monteiro et al. [2016], inter-institutional dialogue is crucial for establishing a collaborative framework. They describe the current challenges, visions, and potential of out-of-school educational places, such as science museums and centres of science and technology, by providing specific examples of research educational programmes and practices in Brazil and other international contexts. Traditionally, both parties (schools and museums/national parks/zoos, or any other institution) have different goals and agendas, often feeling excluded from each other in the decision-making and programme development processes; or they have mutually excluded relationships due to diverse reasons, such as differing goals, expectations, and a lack of communication. The report by Bevan et al. (2010) emphasises that informal science institutions play a vital role in broadening public engagement in science, providing accessible, experiential learning opportunities that complement formal education settings. However, in the case of Chile, not many studies have looked at formal and informal educators working together in collaborative projects (Guerrero & Reiss, 2020).

Thus, adopting a collaborative inquiry approach when reshaping outdoor education from a critical perspective appears essential for developing collective scientific and environmental literacy. Harnisch et al. (2014) illustrate this idea with the expression 'the community is the curriculum', suggesting that outdoor science and environmental education should go beyond fixed curricula and involve engaging in challenging projects, interacting with individuals from different backgrounds and perspectives, and integrating across disciplines, time, and various community-based organisations. For outdoor science and environmental education to be effective, collaborative frameworks between formal and informal contexts, as well as science teachers and 'informal' science and environmental educators from institutions beyond schools, need to be developed, recognising their expertise as education professionals [Guerrero et al., 2023]. This approach could lead to more practical and relevant learning activities in both school classrooms and informal settings such as museums, national parks, and botanical gardens, among others. Consequently, bridging the gap between school science and science learning acquired in informal settings becomes necessary. The second challenge lies in the notion of an epistemic approach to scientific or environmental literacy. Informal institutions, such as science centres, national parks, or museums, primarily share scientific knowledge with visitors through representations of 'experts'' knowledge, which may create another gap in learning. The rich resources and attractive contexts of informal learning environments have significant potential to enhance students' science learning and critical thinking, resulting in the development of scientific literacy. Nonetheless, as highlighted by Monteiro et al. [2016], a more critical viewpoint is necessary when analysing outdoor activities and students' learning in those settings. Unlike the structured approach of school science with its content-based curriculum, informal contexts often significantly engage students with visual and tactile presentations, innovative science and technology exhibits, and opportunities for self-directed learning (Falk, 2001). Therefore, it is crucial to consider the diversity of institutional cultures and, consequently, the range of political or apolitical discourses surrounding scientific and environmental literacies from both formal and informal educators.

The final challenge makes a call for the promotion of critical approaches in outdoor science and environmental education. Kinslow et al. [2019] advocate expanding STEM learning opportunities beyond traditional classroom settings, emphasising the need to address environmental and climate challenges. However, the disconnection between conventional classrooms and these ‘real-world’ challenges poses challenges for both learners and environmental educators. Kinslow et al. [2019], specifically urge science and environmental educators, whether formal or informal, to incorporate such elements as sociocultural, moral, economic, and value-related factors to contextualise environmental learning and foster effective problem-solving.

According to Kinslow et al. [2018], many field-based environmental and science education programmes lack the ability to contextualise and offer meaningful learning experiences for students. This deficiency often leads to a lack of expertise among teachers and to the depoliticisation of certain complex environmental issues in outdoor science and environmental education. For instance, traditional field trips in ecology classes primarily focus on teaching specific techniques, species, or habitats studied in classroom settings (Dillon et al., 2005a; Rickinson et al., 2004).

To promote critical scientific and environmental literacy through outdoor education, Dunlop et al. [2021] present the case of outdoor education and ‘fracking’ as an example where scientific and technological knowledge intersects and conflicts with economic, political, social, and other forms of knowledge. This example could be relevant for Latin America, given the region’s approximately seven thousand fracking wells. Visiting areas affected by fracking could serve as a valuable example to foster critical scientific literacy, helping individuals make well-justified decisions concerning the desirability of actions related to fracking or anti-fracking stances. Dealing with complex social and environmental issues (such as hydraulic fracturing) in the years of compulsory science schooling is necessary because scientific knowledge is necessary but not sufficient to prepare young people for the critical scientific literacy required to meet sustainable development goals [Dunlop et al., 2021, p. 557].

Possibly related to the previous challenge, it becomes essential to elevate these experiences to higher epistemic levels. Many field-based environmental education programmes have attempted to address this gap by introducing citizen science elements, where participants actively collect data and engage in scientific endeavours connected to their communities. However, this approach often falls short of creating epistemically engaging learning activities if the participants merely collect data without considering the broader significance of that information. To overcome this challenge, there are some options to consider. One approach involves explicitly incorporating socio-scientific issues based on the utilisation of controversies, allowing for the integration of complex contextual components into outdoor science and environmental education, including, for instance, ethical and political questions [Dunlop et al., 2021; Kinslow et al., 2018]. By incorporating socio-scientific or socio-ecological issues, these methods offer opportunities to enhance epistemic engagement and facilitate advancements in scientific and environmental literacies.

Finally, to conclude this section, despite evidence of the positive effects of outdoor science and environmental education programmes and the emerging role of museums in fostering unfinished science experiences, Lambert and Reiss (2016) express concerns that rising costs and potential liabilities are prompting policy administrators to reduce or eliminate outdoor learning opportunities. This situation is regrettable since the literature reports opportunities to increase scientific literacy, environmental literacy, and socio-scientific reasoning for students. These learning goals are normally difficult to achieve, and policymakers should consider the potential benefits of field-based environmental education before reducing or eliminating these valuable programmes [Kinslow et al., 2018].

3.3.7 Climate change education and critical scientific and environmental literacies

Climate change is already showing severe socio-ecological threats and consequences for many communities and ecosystems around the globe. Particularly in the last decade, climate change and sustainability literacies have been understood by scholars as deeply linked with scientific and environmental education [Dillon, 2016; Tasquier et al., 2022; Valladares, 2021]. Today, climate change is one of the most pressing problems facing humanity and natural environments globally; hence, the way in which education will respond to addressing this problem is crucial. Climate change is not only an environmental calamity but also an intergenerational and socio-ecojustice issue. Therefore, climate change education is not only about environmental issues, but also about political and ethical endeavours [Eliam, 2022], which should be included as a key component of critical scientific and environmental education, considering collective rights and equality. As a field in constant growth and tension, climate change education must confront such challenges [Prosser Bravo et al., 2022]. Addressing those imperatives, the main focus of this section is to discuss evidence reported in 13 articles which illustrates the intricacies of integrating climate change education to encourage a critical approach towards scientific and environmental literacies.

Climate change education, as emphasised by numerous authors during this period, is a necessity [Bright & Eames, 2020; Colston & Thomas, 2019; Prosser Bravo et al., 2022]. Its significance goes beyond shaping educational systems solely for children and youth; rather, it extends to encompass society as a whole, involving different generations and communities [Gaudiano & Cartea, 2020]. The urgency to address climate change education is evident, requiring collective action and awareness from all levels of society. However, there are two main issues reported in the literature. The first one is related to the scepticism among teachers at the moment of talking about climate change and its consequences in science and environmental education. Secondly, there is a lack of a broader consensus about how to articulate climate change education within the school curriculum. Consequently, it seems to be unclear how teachers are adapting their pedagogical practices in order to incorporate new topics related to the climate crisis in their classrooms.

Notwithstanding the abundance of scientific evidence and consensus, in a world overwhelmingly filled with fake news and ideological discourses, certain individuals continue to express doubts regarding the Anthropogenic causes and the existence of the climate crisis [Colston & Thomas, 2019]. According to Valladares [2021]:

> Undoubtedly, we are experiencing a strong security crisis and we are dealing with different forms of violence and systematic violations of human rights that are intertwined in a global context characterized by a political and environmental crisis that could be synthesized in challenges such as climate change, increasing mass migrations, the excessive circulation of misinformation – fake news – as a consequence of massification of digital technologies. [p. 558]

This scepticism and explosion of fake news around climate crisis might be attributed to coordinated efforts by influential political and economic entities seeking to obstruct climate change policymaking, often associated with conservative political movements [Trémoliére & Djeriouat, 2021]. For instance, in the United States, “major actors such as the fossil fuel industry, corporate banking companies, conservative think tanks and foundations, environmental front groups (acting on behalf of the former), and disguised astroturf organisations play a significant role in spreading climate change denial" [Colston & Thomas, 2019, p. 2]. These well-organised campaigns work to perpetuate the notion that climate change education is not of utmost importance. Colston & Thomas [2019], through a critical discourse analysis, unmask three children's school textbooks, self- reported as being authored by climate change sceptics. The titles of these books clearly challenge the scientific consensus on climate change: (1) *Deb and Seby's Real Deal on Global Warming: The 'Other-side' of the Man-made Global Warming Issues*; (2) *The Sky's not Falling: Why it's OK to Chill about Global Warming*; and (3) *We're not scared anymore Mr. Gore (A Climate Change Story for Little Skeptics)*. These discourses are only some examples of how certain groups can contribute to undermining the wider societal recognition of climate change as an urgent problem. The efforts made by certain groups might be hindering the incorporation of climate change education as a potential core aspect of scientific and environmental literacies.

Moreover, climate change education in schools is not receiving sufficient attention. Recent evidence suggests that many teachers are providing conflicting information regarding the impacts of the climate crisis. For instance, some teachers tend to underestimate the consensus among experts on this matter, primarily due to their limited understanding of climate change [Plutzer et al., 2016]. This lack of knowledge can be attributed to the fact that only a few K-12 teachers have received formal initial teacher education on climate change, which acts as a barrier to providing quality climate change education. This is a potential new challenge for initial teacher education in science education globally. To address this issue, pre-service teachers must be supported in exploring the connections between science and society, using discursive pedagogical approaches to develop critical scientific literacy for sustainable development. However, implementing approaches that meaningfully integrate societal and environmental awareness may be challenging. Developing such transformative scientific literacy requires shifts in school science culture, resources, and assessment standards, often within systems that remain focused on conventional science curricula and their assessment, as seen in the case of Chile. Thus, it is necessary to strengthen climate change education from initial teacher education levels to all educational levels to counterbalance sceptical views of the climate crisis and to counteract ideological discourses that attempt to hinder the recognition of the reality of the climate crisis. This training should also be linked with climate change and political literacies.

Climate change literacy refers to the essential knowledge and understanding of the scientific principles governing climate change processes, causes, impacts, and potential solutions [Anyanwu et al., 2015, 2017]. It plays a pivotal role in facilitating well-informed political decisions and promoting sustainable consumption patterns. Climate change literacy also implies actively taking part in action on climate change. Calling for action, this engagement in climate change education should also involve 'minds, hearts and hands' [Wolf & Moser, 2012, p. 550]. However, typically, this concept is proposed as an umbrella term for the various competencies and skills needed to bridge a gap between understanding the sciences of climate change and acting on the grounds of this knowledge (Hoydis et al., 2023). The gap between the two – knowledge and appropriate behaviour – is a well-known psychological problem, variously labelled the 'mind-', 'attitude-'or 'intention-behaviour gap'. The fact that knowing stuff does not necessarily imply a translation of this knowledge into action frustrates researchers across the board. Therefore, there is also a need to analyse how climate change education can be translated in action. This challenge might be solved by aligning climate change education with political and critical scientific literacies, as I argued in the previous section. Political literacy becomes a necessary complement to climate change education, given the intricate link between political and environmental issues. According to Bright and Eames [2020], political literacy provides teachers (and students) with a historical perspective and a deeper comprehension of broader economic, cultural, and social connections. Understanding how political influences shape individual and societal discourses, choices and the subsequent impact of those choices over time is vital for driving social and ethical transformations. However, the challenge to incorporate climate change education and political literacy will require restructuring of (teacher) education at all levels (including teacher professional development programmes).

Regarding the second tension in the literature, scholars and policymakers agree that placing climate change-related subjects on school curricula will help young people cope better with the reality of global warming and other manifestations of climate change, both practically and psychologically [Salinas et al., 2022]. Globally, international institutions have called for climate change studies to be included in schools, as a formal part of curricula. However, and typically, climate change and environmental education is taught in classrooms by integrating the topic into science or environmental school subjects' syllabuses by 'infusion' [Ramsey et al., 1992]. This situation might be considered as part of the never-ending discussion about how to articulate science with environmental education, reported since the 1990s.

Various countries worldwide have attempted to introduce policies and programmes related to climate change education, although they have encountered particular challenges. For example, in Brazil efforts to implement environmental education policies have shown limited effectiveness in influencing the country's mainstream educational, environmental, and climate change policies [Loureiro & de Lima, 2012]. In numerous global curricula, approaches to climate change education can be categorised into two main strategies: integrating multiple subjects or creating dedicated cross-disciplinary segments within the curriculum [Eilam, 2022].

UNESCO's recent international report, *The Climate Change Education Ambition Report Card* (UNESCO, 2022), highlights that several nations are aligning with promoting climate change education and implementing innovative learning strategies. Noteworthy examples include Argentina's introduction of a National Law of Comprehensive Environmental Education in 2021 and Italy's pioneering move in 2019, making climate-related studies compulsory in state schools, requiring approximately an hour per week, 33 hours annually, for addressing climate change topics. Similarly, Cambodia has initiated a policy to incorporate climate change education by expanding the Earth science curriculum in upper secondary schools. Singapore has also examined the inclusion of climate change education within the context of subject prioritisation for national standardised tests [Chang & Pascua, 2017]. China is progressively integrating climate change issues into its educational framework and formulating national climate change mitigation and adaptation policies. It has established a comprehensive climate change mitigation programme and has invested substantially in climate-related initiatives. Education has become an integral component of China's national sustainable development goals and strategies for climate change education [Han, 2017]. In conclusion, on a global scale, there is growing consensus that climate change education should be integrated into curricula through interdisciplinary frameworks encompassing bio-ethical dimensions [Kate et al., 2019], in a strong connection with climate, science and environmental literacies. Nevertheless, and as consequence of the lack of clarity about how to manage the climate change curricula in school subjects' syllabuses, research suggests schools have not been engaging significantly in climate change education [Bagoly-Simó, 2013].

3.3.8 The interplay of scientific and environmental literacies

Within formal education, environmental literacy typically resides within science education, reflecting the assumption that a deeper, structured understanding of environmental issues is essential, beyond common knowledge. This approach is based on the premise that a critical exploration of environmental information demands at least a functional understanding of the principles of scientific data collection and analysis. Scientific literacies seem to provide the language for arguing in favour of ecological or climate action and for promoting critical approaches in environmental education. For instance, concepts and models from science are essential to comprehend climate change (Salinas et al., 2022). However, hegemonic Western science in schools typically serves as the primary means for humans to engage with the environment, paradoxically contributing to the disconnection with the natural world. Thus, until we advance towards a critical scientific literacy aligned with an eco-centric vision, the aspirations of environmental literacy will remain unfulfilled. Both language and models of discovering reality are equally responsible for generating ontological understandings that influence rationality and emotionality in how we connect with nature.

Many educators, particularly those with eco-socialist views who have a significant influence on environmental education in various regions of Global North, typically do not critically examine their own assumptions. Environmental and science educators often blame specific aspects of modernity, such as industrial capitalism, for the ecological crisis, but neglect to question their own human-centred beliefs. Environmental and scientific literacies require challenging anthropocentric, modernist, and humanistic assumptions in an intertwined relationship (Guerrero et al., 2024). Critical environmental literacy, as defined by Stables and Scott [1999], is rooted in "informed skepticism towards all the grand narratives of humanist (and anti-humanist) modernity, including capitalism, socialism, science, and art" (p. 149).

The merging of science and environmental literacies can assist us in rekindling our sense of wonder for the profound mysteries and limitations of life beyond our material needs and logical reasoning. This process of amalgamation involves acknowledging the intricate interconnectedness of human and natural history, comprehending the historical and cultural influences shaping our scientific advancements, technological innovations, and artistic pursuits, and aligning our actions with ethical beliefs and sustainability principles. This alignment guides us as we strive for environmental improvement and assist various entities – human, non-human, or beyond-human – in their respective environments.

3.4. Concluding remarks

In general, critical scientific and environmental literacies have many similarities with other critical literacies approaches in education (e.g., Baró, 1982; Freire & Macedo, 1987;

Vygotski, 1995). Critical approaches in science education take ideas from ‘science for [critical] citizenship’ and democratic participation (e.g., Albe, 2015; Levinson, 2010), Critical Pedagogy (e.g., Freire, 1970; Giroux, 2018; Kincheloe, 2008), Continental European *Bildung* perspectives (e.g., Sjöström & Eilks, 2018), Decolonisation of Science Education (Gilmartin & Berg, 2007), Science and Technology Education Promoting Wellbeing for Individuals, Societies and Environments STEPWISE (Bencze, 2017) and STSE (Science, Technology, Society, and Environment) education (e.g., Pedretti & Nazir, 2011), going beyond the ‘traditional’ understanding of scientific literacies in the literature.

According to Hodson (2011), the principal goal of critical scientific literacies should be that all students, regardless of gender, ethnicity, religion, sexual orientation, geographical location, and current attainment levels, must achieve a measure of critical scientific literacy, which he interprets as the capacity to read reports involving science in all forms and multimodalities of communication in an informed and critical way, in order to form one’s own judgement about what to believe, what to doubt, and what to reject. He believes in a universal critical scientific literacy that all pupils can engage in at some level. The concept of critical scientific literacy considers the promotion of educational processes to articulate scientific literacy with political and environmental literacy (C. E. Roth, 1992), in order to increase social and environmental justice. A critical scientific and environmental literacy-based approach would imply that teachers, scientists, science and environmental educators, and students in general, might have access to scientific and ecological knowledge questioning the sources of fundings in science and the impact of economic development not only on the environment but also on social aspects, and lastly recognising that science is also political, has history and context (Hodson, 2010). This means promoting educational processes based on emancipation and transformation that articulate scientific literacy with social and environmental justice.

After more than 20 years since the review carried out by Hart and Nolan (1999), we can assert that a critical approach to environmental education should encompass promoting a critical and politicised orientation towards environmental literacy, addressing political and economic context issues within environmental education, and fostering community environmental awareness and action. For instance, recognising that ecological issues are complex and that there are need for inter- and transdisciplinarity, emphasising the value of nature experiences, understanding that all human activities have an impact on the environment, and emphasising that learning processes are as important as content itself (St

Clair, 2003) for fostering world-centred agency Biesta (2022). According to Stables and Scott [1999], critical environmental literacy is rooted in "informed skepticism towards all the grand narratives of humanist (and anti-humanist) modernity, including capitalism, socialism, science, and art" (p. 149). I believe that climate change literacy can be seen as a part of critical environmental literacy.

In the Portuguese and Spanish literature reviewed, the conception of critical literacies is framed typically on Freire's work, where literacy is understood as a process of critical awareness (conscientisation), which means that teaching a person to write or read (or to learn about science) is not enough if we are not considering also a process of liberation of consciousness towards the integration of personal reality and transformation (Freire, 1970). Teaching science from conscientisation and using territorial socio-scientific issues implies new and complex challenges for educational systems at the structural and epistemic level. For this challenge, it is important to rethink the epistemology of the subject in the world, that is, to analyse which subject we want to educate and for which society. A comprehensive view of the individuals would have implications at the socio-emotional level, in learning, teaching, in the pedagogical interactions, and spaces, among several other aspects. Public policies, teacher training programmes, schools, and teachers must reflect on these aspects and apply their learnings to achieve the required transformations towards a more just and equitable society. In other words, a process of scientific conscientisation might imply understanding the role of science, in harmony with the position of the human beings within nature. This process involves a transition towards understanding society in interdependence with nature and not as it is currently done through a false human-nature dichotomy. Scientific and environmental conscientisation involves developing the ability to critically understand interpersonal connections, the essence of humanity, and the causes and consequences of our actions in relation to others. This approach should be integrated with dialogues across critical pedagogies, feminisms, and framed within the decolonisation of science education (Gandolfi, 2021). My main argument for this is because these theories share foundational goals: fostering dialogue and reflection, embracing diverse perspectives, systematically analysing reality, and empowering students' voices. In practice, educators can achieve this by, for instance, being active actors at designing curricula that include collaborative projects, and through discussions on the socio-cultural implications of scientific knowledge.

The concept of critical scientific literacy considers the promotion of educational processes to articulate scientific literacy with political and environmental literacy (C. E. Roth, 1992), in order to increase social and environmental justice. A critical scientific and environmental literacy-based approach would imply that teachers, scientists, science and environmental educators, and students in general, might have access to scientific and ecological knowledge questioning the sources of fundings in science and the impact of economic development not only on the environment but also on social aspects, and lastly recognising that science is also political, has history and context (Hodson, 2010). This means promoting educational processes based on emancipation and transformation that articulate scientific literacy with social and environmental justice.

All of the above conscientisation in critical approaches means promoting educational processes based on emancipation, transformation, and, primarily, hope. It entails scientific and environmental literacy, which seeks and allows the realisation of social and environmental justice. It involves understanding the role and position of a human being within nature and society, as well as the ability to critically comprehend interpersonal connections. It delves into the meaning of being human and analysing the causes and consequences of our actions when interacting with others. Therefore, nobody is an illiterate or uneducated by choice but because of the imposition of others and as a consequence of their conditions.

Finally, returning to the original focus as outlined in Chapter 1, it is evident that environmental problems and sustainability issues cannot simply be ignored. On the contrary, especially for disadvantaged individuals and communities, the climate crisis – alongside various other crises such as species losses and the 'colonisation' of artificial intelligence – seemingly demands urgent action to promote social justice and environmental sustainability (ecojustice) (Bencze et al., 2024). Within a global context marked by the climate crisis and the widening of other planetary boundaries, these challenges will only exacerbate, with ramifications extending far beyond localised impacts. Consequently, future research in environmental and science education must systematically scrutinise the myths that underpin our thoughts and practices within school systems. This process entails examining the structures and ethos needed to support teachers in reassessing their beliefs and understanding how to adopt new practices aligned with critical literacy approaches. In this sense, it is imperative to recognise the political, ethical, emotional, cultural and economic dimensions intertwined with environmental and science education, as these factors profoundly influence the implementation of educational initiatives in addressing global challenges.

Chapter 4. Empirical Study

This chapter introduces the second part of my PhD thesis, which is built upon an empirical study conducted in Santiago, Chile, between December 2020 and September 2021. Within this chapter, I reflect on my positionality, theoretical and philosophical stance to provide rationale and justification for the methodological decisions of the collaborative and empirical research project. In doing so, and by delving into a detailed step-by-step process, I present the challenges that I faced as a PhD student living in England and Chile during the global COVID-19 pandemic as I initiated a research project rooted in collaborative and participatory research epistemologies within a hybrid research modality. Additionally, this chapter outlines the phases of the contextual fieldwork; elucidates the recruitment process; describes the stages of the project in terms of data production methods; and provides an in-depth exploration of the employed data analysis techniques.

This chapter is structured into three main parts. To begin with, I reflect on my positionality and reflexivity as a teacher-researcher, engaging in a self-reflection process regarding my philosophical foundations, specifically my axiological, ontological and epistemological stances. Subsequently, I describe and justify my theoretical framework based on critical theories, particularly on Freire's concept of *conscientização* (conscientisation). Finally, I present a comprehensive account of the research journey, including my methodology and a timeline of the empirical stage of my thesis based mainly on my fieldwork, data production stages, and some ethical considerations intrinsic to collaborative research. This last main section is divided into three sub-phases: before, during, and after fieldwork.

4.1 Positionality, reflexivity, and philosophical foundations

Reflecting upon my positionality has constituted a profoundly significant process throughout the trajectory of my PhD studies. The impetus driving my engagement in a project of this nature is intricately intertwined with diverse facets of my Latin American identity. As theorised by Mignolo (2017), the concept of 'being Latin American' transcends mere geographic and cultural delineations, encompassing considerations of power dynamics, colonial legacies, and the imperative of decolonisation. This entails not only the interrogation of dominant narratives and examining the fluid and ongoing evolution of identities within the context of decolonisation paradigm. Mignolo's pivotal thesis, developed within his book *The Idea of Latin America* underscores the critical importance of analysing Latin American identities with a theoretical lens that is both critical and decolonial, taking into account historical influences alongside contemporary realities and discourses (Mignolo, 2017).

With these notions firmly in mind and reflecting upon my four-year journey as a PhD researcher living in England, I have come to a recognition of the need to interrogate the prevalent nature of hegemonic narratives penetrating education and specifically scientific and environmental education discourses (Roth & Barton, 2004). These narratives have been penetrating the pedagogical background of Latin America and Chile. For instance, the hegemonic idea of scientific literacy extends to the homogenous cultural bubble of science and, as a consequence, to the perception of the environment, often based on a dichotomous ontological position between humanity and the natural world (Zaratiegui, 2018).

My positionality also encompasses my experience in Chile as a science and environmental educator and my prior role as a teacher-researcher engaged in collaborative and participatory research projects (see Guerrero et al., 2019; Guerrero & Fernández, 2020). In this role, I had the opportunity to be working with more than 30 Chilean teachers from different schools. Working as a co-researcher with teachers, I realised the importance of considering teachers' voices as researchers and active actors at the moment of imagining a collective transformation in education. Moreover, my active participation as a political and environmental activist in different unions during my period as a student at my university in Chile was crucial in my professional development to considering education as a political endeavour for social and eco-justice.

Demographically speaking, I identify as a member of a working-class family, where most of my family did not have the privilege of formal education. My parents progressed only to the latter stages of elementary education. My grandmother with whom I grew up is illiterate. All my family is from a mixed ethnic background. Therefore, I consider myself as a 'mestizo', a person of mixed race having indigenous (Mapuche) and Spanish descent. My childhood and adolescence were shared with my illiterate grandmother and with my sister in a hometown on the outskirts of Santiago, specifically in the district known as Maipú.

While my family did not directly endure the horrors of the civic-military dictatorship – an era that impacted 68 of our neighbours in Maipú and some 40,000 victims in Chile (INDH, 2024) – I have come to recognise how this period of oppression, murder, and intimidation, alongside the subsequent implementation of neoliberal policies in Chile, has cast profound shadows across various dimensions of my family's and my own life. These impacts extend to access to healthcare, a dignified pension system, cultural enrichment, and the fundamental right to a quality education that is free, equitable, and accessible for all.

Moreover, I have witnessed the impact of neoliberalisation of Chilean society in almost all dimensions of life, including the neoliberalisation of nature (Villavicencio, 2021). Those policies were implemented by the civic-military dictatorship since 1973. These neoliberal reforms are based on privatisation, commodification, deregulation and cuts in public expenditure for environmental management (Liverman & Vilas, 2006). For instance, neoliberal policies that were developed during Pinochet's period have had a significant impact on nature, leading to profound and radical changes in environmental regulations related to fisheries, water resources, tree plantations, copper mining, among many others (Galaz, 2004).

Since childhood, I was immersed in narratives recounted by my grandparents and parents, sharing stories of the military's violence and intimidation during the 17 years of Pinochet's dictatorship in Chile. These stories fortified my determination to become a teacher and to envisage a more just and equitable country. Upon completing secondary school, I achieved a milestone by becoming the first member of my family to enter university. This educational journey at the University of Santiago marked a pivotal phase in my life. This period granted me the opportunity to examine deeply the repercussions of neoliberal policies, endowing me with profound insights and empowering me to commit myself towards social and ecological justice with unwavering conviction.

4.1.1 Ontology, axiology and epistemology

Considering the previous section, my background and identity shaped my worldviews and, consequently, my epistemological, ontological and axiological positionality. As a researcher, my philosophical stance is based on an axiology that views the environment as having intrinsic values and rights. In my understanding of natural reality, humans, non-human entities, and more-than-human entities all have inherent worth and the right to exist. The origins of the term 'more-than human entities' appear to be in the field of cultural geography (Whatmore, 2008), and refer to beings, forces, or phenomena that transcend human capabilities and exist beyond the conventional boundaries of humanity (Hodgets & Lorimer, 2015). These entities can include deities, supernatural beings, and other non-human actors that significantly impact or interact with human life and society. This perspective contrasts with the anthropocentric view of the environment (Kortenkamp & Moore, 2001), providing a conceptual framework that goes beyond the traditional human-centred perspective and acknowledging the interconnectedness and interdependence between humans and non-human entities within complex ecological systems.

My axiological and ontological position is based on a biocentric understanding of the world. In ecocentrism, all living entities possess inherent individual value independent of their utility to humans. However, ecocentrism "goes beyond biocentrism (ethics that sees inherent value in all living things) by including environmental systems as wholes and their abiotic aspects" (Washington et al., 2023, p.1). Thus, my positionality considers human beings as part of a more extensive ecological network in the natural world, considering health and integrity of ecosystems and the Mother Earth as the central ethical concern. This network is founded on the interdependence and interconnectedness of all life forms and complex, integrated ecosystems.

Epistemologically speaking, I consider there are limits to what humans can know or understand. I recognise my knowledge limitations as a human being in comprehending phenomena beyond my limited capacity to perceive the world. In that sense, knowledge and truth can be relative to different cultures or societies. Moreover, although knowledge is a collaborative effort influenced by cultural factors (Vygotsky, 1962), I recognise that knowledge is to do with the material and natural as well as the social. In Section 4.2, I will expand on my positionality about an epistemology for collective action.

My philosophical foundations also incorporate spiritual or mystical elements based on ancestral biocentric indigenous ontologies which recognise and emphasise nature as sacred, along with a spiritual connection between humans and the natural world. This approach is intertwined with the ideas of Acosta (2018) by incorporating the indigenous philosophy from indigenous communities from the Andes in South America, called '*Buen vivir*' in Spanish, '*Sumak kawsay*' in Kichwa, and '*Suma qamaña*' in Aymara. In English, although there is not an English phrase that perfectly encapsulates the essence, the concept it is often translated as 'good living' (Cunningham 2012). According to Acosta (2015), *Buen vivir* emphasises community well-being, reciprocity, solidarity, and harmony with *Pachamama* (Mother Earth). This approach is significant for three key reasons. First, social development is not incorporated in the state's plans as necessary for the achievement of economic growth. Secondly, having resisted colonisation for centuries, indigenous peoples and their philosophies are valuable connections to a variety of pre-capitalist and non-capitalist cultures.

Indeed, and finally, this ontological approach reminds us that there are alternatives to capitalist globalisation and neoliberal systems.

Buen vivir envisions a deep connection between humans and the natural world (Gudynas, 2012; Walsh, 2010). Humans are not distinct from the Earth or other entities; instead, they constitute an integral part of the biosphere, and, consequently, they bear the responsibility of fostering the vitality of *Pachamama* (Figueroa-Helland & Raghu, 2017). There are similar notions to *Buen vivir* among diverse indigenous people, such as the Mapuche (Chile and Argentina), the Guarani (Paraguay, Brazil, Argentina and Bolivia) and the Kuna (Panama and Colombia). Gudynas (2012) proposed an eco-centric ethic in recognising and assigning values and a de-commercialisation of social relationships with nature. These processes also encompass a process of decolonisation of knowledge, a rupture with the rationalities of manipulation and instrumentalisation of people and nature, dialogue between sources of knowledge, and expanded relationships with nature, including communities and non- and more-than human entities (Gudynas, 2012; Le Quang, 2013).

I consider that these principles are crucial to developing a collaborative research project about environmental and outdoor education. They are even more special for me because of the location of my fieldwork in the Andes Mountains in Chile, where many indigenous communities have lived in the past.

4.2 Theoretical framework

Reflecting on my theoretical framework in education has not been a simple task, but that does not mean it is a process that I have not deeply enjoyed. During my training as a physics teacher in Chile, and I would even dare to say that during my master's and PhD training, there was little or no discussion, both individually and collectively, about the meaning and importance of theory in science and environmental education. Consequently, the relevance of a theory about learning and teaching was not something that was explored in any depth during my training as a teacher. Now, in the final year of my doctorate, I strongly believe that in education, in general, the theory selected to analyse, describe, and understand the world is crucial. A central question for any curriculum or pedagogical theory might be what knowledge we should teach in schools. This question demands critical reflexivity and drives us to the discussion of what students need to know. What is valid, necessary, or essential knowledge, for instance, within science and environmental education?

Those are some questions I started to reflect on when considering theories about critical literacies and outdoor science and environmental education. This was not a solitary but a collective process with some Chilean colleagues with whom I wrote collaboratively about critical theories applied in outdoor education (see Guerrero et al., 2023). After three years, some of my/our reflections have been also discussed with colleagues from Brazil, Spain, Colombia, Mexico, Turkey, Canada, UK, and Sweden. Now, I am expanding my ideas in this section as part of my theoretical framework.

4.2.1 Theory and critical approaches

According to Da Silva (1999), a theory should offer an image of the real world. In principle, a theory should serve as a mirror to discover, reflect, and represent reality. However, theories in education not only describe the world; in addition, by describing it ontologically, they re-create and produce the reality with which they are dealing. This process seems paradoxical because a theory first creates and then discovers, but through a rhetorical device, what it creates ends up appearing as a discovery (Da Silva, 1999). However, Da Silva (1999) pointed out that traditional theories in education are traditionally theories of agreement, tolerance, adjustment, and adaptation. In contrast, a critical approach, when thinking about theory, might distrust the status quo, holding it responsible for social inequalities and injustices. This marks the critical reflection stage of how I came to consider critical theories in my research. I use the term ‘critical theories’ in the plural because I am conscious of the broad spectrum of their approaches and understandings.

Originating from the ‘Frankfurt School’ as a re-examination of Marxism, critical theories follow a heuristic approach but lack a single, definitive definition (Scott & Marshall, 2005). Critical theories are traditionally committed to challenging domination and social inequality through scepticism, questioning, and radical change (Hayward, 2007). They encompass various perspectives that critique the role of schools, curriculum discourses, and pedagogy in shaping and reproducing knowledge (Barbosa, 2017). Rather than focusing on curriculum implementation techniques, critical theorists emphasise understanding what the curriculum achieves. A key goal of critical theories is to inspire social and political change, often revolutionary, as noted by Brookfield (2005).

In the context of science and environmental education outside the classroom, critical theories might take a critical stance toward society and adopt an ideological focus (Patrick, 2023). This focus is typically associated with highlighting the analytical significance of sociohistorical context, promoting a collaborative emancipatory agenda, advocating for social and eco-justice, and embracing reflexivity.

My theoretical framework is based on critical theories, particularly on critical approaches framed around the extensive work of Paulo Freire and certain ideas from environmentalism based on Marx's eco-socialism (Misiaszek, 2023; Saito, 2017). Both are traditions which draw on Marxist scholarship to illuminate the ways in which people accept as normal a world characterised by massive inequalities based on a systematic exploitation of both nature and human beings (of many by a few of them).

From my experiences presenting at conferences and discussing with colleagues across the UK, Latin America, Asia, and Europe, I recognise the challenges of using Marx in education, especially within science or environmental education, where it can be even more contentious. The initial reaction often reflects a sense of "Marxophobia" (McLaren, 1997), likely due to associations with the rigid ideologies of authoritarian communist regimes. However, critical theories engage with Marx through ongoing dialogue, not as a fixed or dogmatic system of absolute truths (Gramsci, 1971; Jay, 1973). As Gramsci (1988) reminds us, "Marx is not a Messiah who left a string of parables laden with categorical imperatives, with absolute unquestionable norms beyond categories of time and space" (p. 36).

Gramsci understood that Marxist ideas are always a provisional value. In this sense, critical theories are open to development and revision, as seen in the last years through several important reformulations regarding, for instance, the revision of class concepts, the analysis of power by Foucault, and some postmodernist critiques, among others (Brookfield, 2005). As the world remains unfinished, theories require a continual process of reinvention, grounded in critical self-reflection (Misiaszek, 2023). The local adaptation of theories can yield authentic *praxis*; without this local contextualisation, theories cannot provide viable solutions to local problems (Gaddoti, 1996). However, this process of theory reinvention should be rooted in bottom-up decision-making and actions, taking into consideration the voices of local communities and insights derived from addressing specific territorial issues. Therefore, in my thesis, my critical theory approach is framed by specific historical and material conditions in the Global South, specifically in Latin America, particularly Chile, and guided by philosophical foundations discussed in the preceding section. My theoretical framework is positioned as part of a wider intellectual debate concerning a systematic, critical engagement and updated Marxist analysis, in my region, under capitalist and neoliberal material and historical conditions. In this sense, I am aligned with the following statement:

"critical theories are the product of particular social, political, cultural, ethical, and intellectual milieus" (Brookfield, 2005, p. 32).

Finally, my justification for why I am using critical theories in my project is because this tradition is a concern with practical projects based on collaboration and participation to help communities and participants in directions they determine (Brookfield, 2005, p. 26). Additionally, I believe it is important to recognise that every individual is a theorist capable of contributing new epistemological insights for collective action. To quote Gramsci (1971):

> people who participate in a particular conception of the world, have a conscious line of moral conduct, and therefore contribute to sustain a conception of the work or to modify it, this is to bring into being new modes of thought. (p. 9)

The validity of a critical theory lies in the extent to which participants feel it reflects their aspirations, translating theory and knowledge into practical actions. As educators, our actions are often guided by our understanding of how the world operates; we act on our implicit and explicit theories, expecting certain outcomes. In collaborative projects, openly sharing our theories can foster dialogue and enhance our understanding and actions. A theory, as Brookfield (2005) notes, "is useful to the extent that it provides us with an understanding that illuminates what we observe and experience" (p. 5). Discussing theory enables us to identify and reframe aspects of our experiences that may be unclear or perplexing.

4.2.2 Critical theory based on conscientização

My critical theory approach in this thesis involves tasks like challenging dominant ideologies, uncovering power structures, contesting hegemony, addressing alienation (including from nature), and fostering liberation, hope, reason, and dialogue (Freire, 1970; Hailwood, 2015). This process is rooted in dialogue and aims to thoroughly explain the development of social and political awareness (Freire, 1979). Following Freire's vision, this approach seeks a more just and compassionate society through *conscientização* (Freire, 1970, 1972, 1979).

It is noteworthy that *conscientização* was first introduced by Alberto Guerreiro and Alvaro Pinto in 1964 (Freire, 2001). While Freire was not the originator, *conscientização* remains central to his educational theories. About the meaning of conscientização, Cruz (2012) defined etymologically the concept as:

> (…) conscientização comes from the Latin *conscientia*, which means joint knowledge, consciousness, feeling or sense. In Portuguese, the noun is consciência, and the verb conscientizar exists, meaning to raise somebody's awareness. The word

> conscientização was formed by adding the suffix -ção to the verb conscientizar, thus creating a new noun; -ção refers to the process and, therefore, conscientização can be literally translated as the process of raising somebody's awareness. (p. 171)

Thus, *conscientização* stands for the development of critical awareness awakening. Before explaining and introducing the complex and evolving meaning of *conscientização* in more detail, I start by introducing and contextualising the work of Freire because this is relevant for justifying my positionality and indicating why there are potential options for applying the work of Freire specifically as a theoretical lens for science and environmental literacies.

Freire was imprisoned for seventy days in 1964 for alleged communist activities and subsequently exiled after a military coup. He lived in Chile from 1964 to 1969, where he authored *The Pedagogy of the Oppressed*, now one of the most-cited books in the social sciences. Though often overlooked, this influential book was written in Chile, a fact crucial for understanding the socio-political context shaping Freire's development of *conscientização*.

Within the broader context of the Cold War, Chile underwent a process of increasing mobilisation of popular forces aimed at achieving significant and fundamental social transformations. Holst (2006) examined Freire's time in Chile, focusing on the socio-political and economic context of *The Pedagogy of the Oppressed*. During this period, the Chilean Agrarian Reform prioritised adult literacy and *conscientização* to modernise rural areas, integrating peasants into cooperatives and unions. This reform redistributed income, opportunities, and benefits from land ownership to both cultivators and society at large (Avendaño, 2017).

Freire's fieldwork in rural Chile enabled him to refine his literacy methods, revealing the limitations of gradual reform for achieving radical change (Holst, 2006). His approach, shaped by philosophical foundations, aligned with the increasing radicalisation among rural working-class groups mobilising for social change. Freire's literacy programmes used generative words and cultural circles, rooted in the socio-political and cultural realities of illiterate populations, emphasising *conscientização* as a collective, context-specific process (Freire, 1979). The growing radicalisation of Chilean worker and peasant movements underscored the importance of dialogue and education's political nature, which I incorporate into my research positionality.

With this context, I will now explore *conscientização* as defined by Freire (1970, 1975, 1979, 1992, 1994, 2005) and other critical pedagogues (Cruz, 2012; Dussel, 1988; Elias, 1976; Smith, 1976). According to Souza de Freitas (2012), *conscientização* is central to Freire's critical theory, representing a process of examining the relationship between consciousness and the world, essential for developing human responsibility within specific historical and social contexts. This process involves engaging with reality through human praxis, allowing individuals to actively shape and transform their world and themselves. *Conscientização* transcends mere awareness, as it involves a critical evolution of becoming conscious since "becoming conscious is not yet conscientização, given the latter consists of a critical development of becoming conscious" (Souza de Freitas, 2012, p. 70). For Freire, there are two prior levels before critical consciousness: naïve consciousness and magical consciousness (Smith, 1976). In the first level, a *naïve* person simplifies and romanticises reality, trying to reform unjust individuals, assuming that the system will work properly. In the second level, magical consciousness is when individuals adapt or conform fatalistically to the system (Smith, 1976; Dussel, 1998). For Freire (1970), *conscientização* requires engagement of the transforming action that: "does not stop, stoically, in pure, subjective, recognition of the situation, but, on the contrary, prepares human beings, at the level of action, to fight against obstacles to their humanization" (p. 119).

Hence, this commitment involves active participation, not merely an awareness of the reality, but also a dedication to actively strive for its transformation. According to Freire, there exist three primary stages or fundamental questions in this process: First, what are the issues within this context (termed 'naming')? Secondly, why do these issues exist (termed 'reflecting' process')? Lastly, what actions can be taken to alter this situation (termed 'promoting acting')? Nonetheless, *conscientização* is not a method for transmitting information or providing skills training; rather, it is a dialogical process that unites individuals to collaborate in addressing shared existential challenges. These challenges typically revolve around the socio-political conditions affecting those engaged in the educational process. Freire (1970), defined *conscientização* as:

> The process in which individual, not as recipients, but as knowing subjects, achieve a deepening awareness both of the sociocultural reality that shapes their lives and of their capacity to transform reality. (p. 519)

In the words of Freire (1972), *conscientização* "always will include a critical insertion into a process, it implies a historical commitment to make changes" (p. 5). In this sense, *conscientização* "is the most critical approach conceivable to reality, stripping it down so as to get to know the myths that deceive and perpetuate the dominating structure" (p.6).

The basic pedagogical differences between *conscientização* and other forms of education is that questions posed by a *conscientização* model of education have no known answers. In this sense, for instance, science education based on *conscientização* is not only a pure organisation of contents or facts to be discovered by the ignorant. It is not simply discovering or calculating the value of gravity, for instance. *Conscientização* is based on a collaborative approach in education to answer unsolved or wicked problems faced by a group of people. This is relevant to my project because to answer wicked problems there are not 'experts' who know the answers and whose job is to transmit or reproduce the answer. On the contrary, individuals come together with a number of valid but different perspectives in terms of axiology, epistemology and ontology, sharing problems which have yet to be precisely defined, seeking answers which have yet to be fully formulated.

Furthermore, *conscientização* is closely intertwined with two more concepts: on one hand, *dialogue* and on the other, the concept of *praxis* which involves a dialectic relationship of reflection and action with others (Dussel, 1998; Freire, 1994). In this sense, participation and collaboration are not only convenient pedagogical tools, but they are also the heart of the pedagogical process (Freire, 1979). Therefore, *conscientização* in my research project is not a simple goal; it is the ultimate goal when we talk about collaborative research and critical scientific and environmental literacies.

Freire's use of *conscientização* evolved over time. Initially, he defined it as the purpose of education, emphasising reflection, critical attitude, and commitment to action (1970). This aligns with the goals of scientific literacy discussed in Chapters 2 and 3. However, by the mid-1970s, Freire moved away from the term due to widespread misunderstandings, as some misinterpreted it as a magic pill for societal change (Smith, 1976). He revisited *conscientização* in *Pedagogy of Freedom*, underscoring its role as a form of critical resistance, particularly relevant in addressing the influence of neoliberal policies on education (Freire, 1998).

***4.2.3 Neoliberalism and* conscientização**

In a general sense, neoliberalism involves the idea that human well-being can be reinforced by freeing up private interests, commodification, managerialisation processes, entrepreneurial initiatives, and free markets (Giroux, 2004; Harvey, 2007). Gilbert (2013) describes neoliberalism as a “discursive formation, a governmental programme, an ideology, a hegemonic project, [and] a technical assemblage” (p. 7). As a theory, neoliberalism can be conceptualised as a group of political-economic ideas and practices inspired by the creation of free-markets and profit-making which emerged as a solution to the crisis of accumulation of capital that had threatened the interests of elites around the globe (Harvey, 2007). Thus, neoliberalism can be understood as a complex social, cultural and social phenomenon that deserves specific consideration in the diverse contexts in which it is manifested.

In *Pedagogy of Freedom* (1998), Freire is very explicit about the threat posed by neoliberalism and underscores the importance of *conscientização* as a means of recognising the ‘obstacles’ brought about by neoliberalism and as a foundation for overcoming these obstacles. Freire extensively discusses the catastrophic impact of neoliberalism on everyday life and within the realm of education. He adamantly opposes neoliberalism and globalisation, which promote an ethos centred on the marketplace and lead to “increased wealth for the few and a rapid rise in poverty and misery for the vast majority of humanity” (Freire, 1998, p. 114).

Unveiling the detrimental effects of neoliberal philosophy in science education can be addressed through a deeper and critical awareness of the socio-political-economic reality (Weinstein et al., 2023). By following the path of *conscientização,* we can challenge both neoliberal philosophy in education and the commodification of nature. However, it is important to note that in this era, the political dimension is not the sole relevant aspect; the ethical, aesthetic, epistemological, and emotional dimensions of the act of knowing are also complementary. *Conscientização* then requires the development of criticality, which, together, with epistemological curiosity, potentiate the creativity of transforming action vis-á-vis limit situations (Dussel, 1998). Thus, criticality, creativity, and curiosity are essential components of the complexity of the relations that situate *conscientização* in the field of possibilities and hope. In this sense, *conscientização,* according to Freire, is based on an ethical-critical principle in the development of consciousness.

In concluding this section, I must acknowledge some criticisms and objections to the political-educational proposals of Freire (Alves de Menezes & Gonzaga, 2018). Gadotti (1987) and Alves de Menezes and Gonzaga (2018) summarise that since the 1960s, Freire has been labelled as a ‘subversive communist’, ‘national-developmentalist’, ‘Catholic neo-anarchist’ and even a ‘useful idiot’. Politically speaking, Freire has faced numerous ideological critics. He has often been seen as an ‘idealist’, a ‘reformist’ and ‘liberal’ as, for some, he does not seek to overcome the capitalist system and deviates from the assumptions of historical and dialectical materialism. Controversially, Alves de Menezes and Gonzaga (2018) identify many instances where Freire was considered an 'eclectic' and 'uncommitted' person, surrounded by communist individuals or so-called 'bad company'.

Freire generally avoided controversy and acknowledged his own naivety, often clarifying his positions when they were misunderstood or distorted. However, he firmly rejected criticisms suggesting indecisiveness on class issues (Alves de Menezes & Gonzaga, 2018). According to Smith (1976), Freire's complex and abstract writing style, along with loosely defined concepts like 'liberation' and 'increasing consciousness', often led to misunderstandings. I approach Freire's concept of *conscientização* with humility, viewing it as a dynamic, evolving term. In this thesis, I aim to incorporate *conscientização* into my theoretical framework and methodology, while remaining aware of my own interpretative limitations.

4.3 Methodology

The methodology employed in this empirical section of my PhD thesis is framed within a socio-critical paradigm (Habermas, 1984, 2012) and based on qualitative research methods. This paradigm is characterised by its emancipatory nature and alignment with critical theories because it aims to transform social reality through the active participation of members of a community (Habermas, 1984). This paradigm is rooted in the fundamental assumption that education and research are not neutral. It asserts the impossibility of obtaining unbiased knowledge, as the idea of the neutrality of science is inherently false (Brookfield, 2005) and invites participants in a collaborative project to engage in a process of co-reflection and to analyse the society in which they are involved, seeking possibilities for change and transformation. For this reason, this approach leads participants in a collaborative research project to collectively reflect on and critique the social reality (Basden, 2011).

The use of a socio-critical paradigm is essential to my methodology, as it involves a critical examination of societal structures, power dynamics, and inequalities (Habermas, 1984). While I intend to explore deeper into this aspect within my theoretical framework, it is important to note that a socio-critical approach implies a methodological focus on addressing issues related to eco- and social justice, oppression, and inequality. For instance, and based on my positionality, my methodology aims to amplify voices within the research process. The emphasis of my project is on learning and teaching but also on *praxis*, which demands co-reflection for collective action. This process is, therefore, a collaborative process and involves different voices and perspectives. Similarly, a socio-critical approach necessitates critical reflection of our own experiences, viewpoints, and assumptions. This process is in dialogue with a co-reflection process, which emphasises collaboration and respectful dialogue among participants and researchers to jointly construct knowledge.

My methodology involves the use of qualitative research methods since my primary objective is to gain an in-depth understanding and interpretation of human experiences, behaviours, and perceptions (Creswell & Poth, 2018). In this regard, my priority is to generate data rather than merely collect it (Merriam & Tisdell, 2015). Additionally, I acknowledge the subjectivity of my participants through a reflexive process (Bourke, 2014), particularly in relation to my own biases and positionality described in Section 4.1.

The second part of my thesis explores outdoor education as a platform to foster collective critical scientific and environmental literacies. The project involved five pre-service teachers, two in-service teachers, two scientists, and two park rangers who engaged actively at various stages. My qualitative methods included interviews, document analysis, focus groups, dialogical seminars, and a photo- and video-recorded field trip, all described in later sections.

This project emphasises bidirectional collaboration, allowing participants and myself to work together in an interdisciplinary, participatory research model inspired by Community-Based Participatory Research (CBPR) (Hacker, 2013) and specifically framed by Collaborative-Participatory Research (CPR) approaches (Wallerstein & Duran, 2006). These methodological choices aim to bridge researchers and practitioners, enhancing professional development, pedagogical reflection, collaboration, and valuable findings for local communities (Cochran-Smith & Lytle, 2009; Guerrero & Fernández, 2020). The main objective of the empirical component of my study is to address two of my research questions:

1. How can a collaborative methodological approach enhance the expertise of pre-service teachers in outdoor education?
2. To what extent can critical scientific and environmental literacies be promoted through outdoor science education?

4.3.1 Collaboration in the research process in outdoor education

When developing outdoor education for schools, particularly in science and environmental education, one needs to acknowledge that a series of obstacles exist and a certain level of expertise is needed (Ayotte et al., 2017). There are many logistical challenges, including: a school’s bureaucracy; pressures to fulfil the statutory curriculum of the subject; financial costs of trips; connotation of outdoor science as leisure-time and, consequently, a loss of time for teaching, along with an increase in the number of extra-academic activities in which students participate (Rickinson et al., 2004). Therefore, partnerships and collaborations with other actors seem an appropriate way to tackle difficulties in planning to improve and support activities outside classrooms (see Guerrero & Reiss, 2020). Aimed at working to address this issue and my first research question, a methodology based on collaborative approaches could support pre- and in-service science teachers in developing activities outside the classroom. In addition, collaborative approaches can help contextualise research to local territories, considering community needs.

One of the goals of collaborative research is to create or increase bidirectional connections between different participants and encourage community partner engagement in every aspect of the research (Hacker, 2013). This approach intends to increase the value of studies for both researchers and the community being studied (Viswanathan, 2004). Furthermore, collaborative research is designed to ensure and establish structures for participation by communities affected by the issue being studied (Hacker, 2013). Along with these definitions, there are a set of principles based on assumptions, including: (a) genuine partnership means co-learning (for instance, academic, teachers and community partners learning from each other); (b) research efforts need to include capacity building (in addition to conducting the research, there is a commitment to training community members in research); (c) findings and knowledge should benefit all participants; and (d) collaborative research involves long-term commitments (Israel et al., 2005). In this project, collaboration is further understood as necessary to endorse ecojustice education as a tool for addressing power imbalances (Sperling & Bencze, 2015). Therefore, collaboration can contribute to blur boundaries among researchers, teachers, scientists, science educators, and park rangers with different backgrounds, identities and trajectories.

4.3.2 The role of science educators and collaborative research

One of the main purposes of educational research has been to produce knowledge for improving education practices inside schools and university classrooms (OEI, 2015). However, even though science and environmental educators are crucial for achieving better teaching and learning processes, they are usually underestimated as active agents and protagonists of their own practice (Biesta, 2017; Kincheloe, 2003). Rather, they are often viewed as a means for implementing policies and research findings that preserve a technical conceptualisation of their role (Gandin & Gomes de Lima, 2015; Schön, 1987). This has resulted in a problematic issue from different positions; policymakers and educational authorities have observed with concern how some policy efforts tend to fail or have unexpected outcomes (OEI, 2015). Traditionally, university researchers have aimed to support teachers to incorporate educational findings into their classrooms, but they have not always been able to produce pertinent knowledge from teachers' perspectives (Pesti et al., 2018). Consequently, pre- and in-service teachers typically perceive research as an area distant from their classroom practice, and even as irrelevant to their daily practice (Beycioglu et al., 2010). This phenomenon might be also extended to park rangers' experiences at the moment of reflection about the relevance of research in education.

Critical pedagogues and scholars address this problem from a more complex perspective on the nature of teachers' work as creative, research-based and transformative (Freire, 1970; Giroux, 1988). For Kincheloe (2003), inquiry is an inherent dimension of teaching, and teacher research has the potential to foster teachers' empowerment. These critical perspectives have sparked many new initiatives on teacher research and continue to be a pertinent lens through which to address issues of empowering teachers and enriching teaching and learning process in the classrooms (McLaughlin & Black-Hawkins, 2007). But even though there have been many successful research studies conducted by teachers that point to benefits for teachers' professional development and meaningful research findings, some scholars, including Cochran-Smith and Lytle (1999), Kincheloe (2003), and Cloonan (2019), have pointed out that practitioner research tends to be subject to critique, since it challenges the traditional positivist research culture. Recognising teachers' research role is considered a pivotal factor when it comes to linking teaching practices to inquiry and reflection, yet this notion has encountered resistance (Biesta, 2007).

Initiatives on teacher research often suggest collaborative research as a fruitful way of incorporating research on teachers' work (Christianakis, 2010; Cloonan, 2019). Therefore, in order to understand, transform and produce knowledge about educational realities, it is necessary to build bridges between different actors and worlds involved in education, starting from an orientation of change with others (Reason & Bradbury, 2008). Recommendations to address the educational gap between teachers and researchers have consistently pointed to a reconceptualisation of the university-school relationship (OEI, 2015). Academia has tended to view teachers mainly as informative actors of educational research and school problems (Beycioglu et al., 2010; Christianakis, 2010); yet the involvement of teachers in research can play a key role in generating research knowledge. Consequently, a collaborative and participatory research-based approach becomes potentially useful and has gained ground from diverse contexts, aspirations, and methodological and theoretical orientations. It has been approached with different labels: action research, associative research, practitioner research, collaborative inquiry, critical inquiry, classroom research, inquiry-oriented teacher education, among others (see Guerrero et al., 2019).

Collaborative research can potentially enhance the role of teacher as researcher and facilitate the professional development of both pre- and in-service teachers (Cheng & So, 2012). This approach seeks to challenge research in education by reconfiguring the role of the university researcher and fostering teachers' leading roles in their professional development. For instance, science educators working in initial teacher education might provide a range of research expertise, training and resources to support teacher inquiry activities, but it is the teachers who ensure that the findings are translated into schools (McLaughlin & Black-Hawkins, 2007). Thus, the alliance between different actors in education also allows us to understand research as a facilitating tool in the construction, elaboration, and validation of knowledge. Moreover, this type of research constitutes an opportunity to link teachers in processes that move from reflection on practice to description, analysis and finally to action (Gray & Campbell-Evans, 2002).

However, bridging the school-university divide implies acknowledging how teachers are viewed during the process of doing research in education. Indeed, this approach demands a new configuration that breaks with the vertical relationships between university researchers and teachers, and where the teachers, no longer mere receptors, are now teacher researchers in dialogue with the university researcher, creating together new knowledge (Freire, 1970). In addition, forming partnerships or alliances is not an easy task, and it requires addressing the cultural and political differences between the work of teachers, university researchers and other actors as in the case of this project. Some of these differences are linked to dissimilarities in the ways that university researchers and in-service teachers tend to frame and deliberate about problems and the design of solutions to problems of practice with colleagues (Reiser et al., 2000). These differences are associated with the expected pace of work and accountability measurement of demands at work (Coburn et al., 2010). For instance, normally pre- and in-service teachers feel a strong sense of urgency; they want solutions quickly so that they can put new innovations in the curriculum or new policies in place to meet students' needs now. By contrast, research and university researchers often proceed gradually, prioritising the production of data and evidence, then analysing through cycles of inquiry, and finally being able to recommend action (Penuel et al., 2015). Indeed, certain limitations regarding school-university partnerships arise from the inherent difficulty of schools and universities substantially changing their cultures, or university faculty becoming complete members of schools, and vice versa. This limitation could perhaps be addressed by drawing on Freire's (1970) insights into the dialectic nature of the research-practice and knowledge dichotomies, thereby blurring the boundaries among entities such as university researchers, park rangers, and teachers. Developing this dialectic process requires acknowledging participants' perceptions of collaborative research and creating suitable conditions, including trust, mutual respect, motivation, resources and adequate time spent in the situational context (James & Augustin, 2018). For instance, Cochran-Smith and Lytle (1992) argued that the knowledge needed for teachers to teach well cannot be generated solely by university researchers and then transmitted for implementation in schools and classrooms.

Engaging in collaborative practitioner inquiry projects that involve collaborative and participatory research approaches could demand the willingness to open a generative new culture, called the third space (Bhabha, 1994), which might allow the negotiation of personal ways of knowing, as well as collaborative understandings in the research process. Here, I agree with Penuel et al. (2015) on the importance of acknowledging the key concept of boundary crossing and the use of boundary practices, which can enrich the understanding of the interactions between research and practice, particularly in the context of collaborative projects.

Boundary crossing involves transcending traditional boundaries between different domains, disciplines, or areas of expertise to foster collaboration, innovation, and problem-solving. It entails "encountering difference, entering onto territory in which we are unfamiliar and, to some significant extent therefore, unqualified" (Suchman, 1994, p. 25). This process necessitates navigating various challenges, including differences in cultures, languages, norms, and expectations. According to Penuel et al. (2015):

> Although boundary crossing are moments when individuals or groups recognise differences, boundary practices are the more stabilized routines, established and sustained over time, that bring together participants from different domains for ongoing engagement. (p. 189)

Moreover, “boundary practices can be defined as new routines that bridge the practices of researchers and those of practitioners as they engage in joint work” (Penuel et al., 2015, p. 190). Both processes encompass the combined efforts of negotiating and managing boundaries between different domains, which requires an understanding of cultural disparities, power dynamics, and variations in expertise among participants. Recognising the existence of professional, cultural and disciplinary boundaries between practitioners and researchers is a crucial aspect of collaborative research projects. However, successfully engaging in this process demands active participation in boundary crossing by all participants (Guerrero & Fernández, 2020).

With collaborative work, science teachers are expected to share experiences with other teachers in their establishment and develop a methodological and research proposal across different disciplines that helps to share pedagogical spaces and break the excessive fragmentation of content in science education (see Guerrero & Reiss, 2019). Additionally, this process requires all participants to engage in boundary practice, and also to pay closer attention to recognising the role and voice of each other in the design and development of collaborative initiatives.

4.3.3 Identity as researchers in collaborative research

The ethical questions that collaborative research in a doctoral project raises, such as around co-authorship and degrees of participation, encourage us to question what it means to produce knowledge, and produce research (Patricio & Santos, 2019). Doctoral students may be drawn to collaborative research because they wish to value knowledge and experience beyond academic institutions, and believe in “democratising knowledge” (Brown, 2022; Lac & Fine, 2018, p. 564). As discussed in Guerrero and Dobson (2024), my decision to engage with collaborative research links to my positionality and identity as a school science teacher-researcher and my desire to involve pre-service and in-service teachers, and other member of the science and environmental education community in the research process as much as possible. I consider this decision as part of my axiological and epistemological positionality – as a core belief in the value of knowing *with* (Haraway, 1988). Yet at times, for a doctoral student, the need to obtain a PhD, and be recognised as a researcher, may feel at odds with the desire to engage in collaborative research. More broadly collaborative research can feel at odds with the elitism and competitivity inherent in academia (Chevalier & Buckles, 2019).

Navigating these questions became even more challenging in the presence of a global pandemic that disrupted peer-to-peer dialogue and in-person collaboration. Accordingly, I will describe the tensions involved in employing collaborative research in my fieldwork, both during and after the COVID-19 emergency, to produce an individual PhD thesis. In the next section 'Fieldwork', I present part of my autoethnographic reflection on the challenges and possibilities faced as a PhD student living in England and Chile during the global COVID-19 pandemic while initiating a CPR project within a hybrid research modality (see Guerrero & Dobson, 2024).

4.4 Fieldwork

My fieldwork, spanning the years 2020 to 2021, was conducted in a hybrid modality and was severely impacted in its original plan and timetable by the COVID-19 pandemic. Consequently, certain initial stages were carried out remotely at the beginning of 2021. Fortunately, and in accordance with the guidelines of the Chilean Government, Chilean Ministry of Health and UCL restrictions, I was able to complete several project phases face to face. I am grateful for the opportunity and permission granted by UCL, as I could not have envisioned conducting my fieldwork based on collaboration and outdoor education solely by Zoom meetings. Some of the in-person stages of my fieldwork took place in December 2020, and then between June and September 2021.

The location of my fieldwork was in the Andes Mountains, specifically in San José de Maipo, Santiago, Metropolitan Region, Chile. The following pages will elaborate in detail the context where the fieldwork was developed, and I will explain the reasons for the location and the hybrid modality stages.

4.4.1 Before fieldwork: Original plan before COVID-19

In the initial plan of my fieldwork, I had formulated some preliminary concepts regarding the integration of science-based field trips with socio-environmental conflicts. Socio-environmental conflicts are defined by Temper et al. (2015) as disputes, tensions, or disagreements that emerge at the crossroads of social and environmental matters. They encompass actions undertaken by local communities and social movements, often involving national or global networks. These actions are directed against specific economic activities, infrastructure construction, or waste disposal/pollution, where the environmental impacts constitute a central aspect of their grievances. My original motivation was to explore collectively some impacts of the climate crisis and two socio-environmental conflicts in Chile.

Originally, I aimed to develop a project framed on collaborative approaches and within the potential socio-environmental conflict in the context of Los Laureles, a town located in the Limache commune of the V region of Chile. This initial idea was to organise a field trip with secondary school students and in-service teachers as part of a collaborative project. The field trip was originally planned to be in a national park close to the site of a thermoelectric project plant named 'Los Rulos', being spearheaded by the Israeli company IC Power. Originally designed as a Combined Cycle (CC) facility, the plant was intended to utilise natural gas for electricity generation, with diesel oil as a backup for emergency situations. Projections indicated that the project would consume 310,000 litres of water daily and emit 110 tons of particulate matter annually (Fundación Terram, 2017). Furthermore, while three indigenous communities (Mapuches, Aymaras, and Diaguitas) were directly affected by the conflict, their involvement was not officially recognised. These communities would have endured significant disruptions in various aspects of their lives and culture, including housing, education, and the preservation of natural areas that held ancestral medicinal significance. However, due to the mobility constraints imposed by the COVID-19 pandemic in Chile and the intricate challenges associated with conducting a collaborative project of this magnitude, it proved unfeasible to progress with this original plan.

As a side note, it is fortunate and relevant for my research project to report that the thermoelectric project plant was abandoned in October 2022. This occurred due to the organisation and activism by the local community, who presented 15 formal complaints against the project (El Desconcierto, 2022). Cerro El Plomo S.A., the Chilean company established to oversee "Los Rulos", chose to withdraw the Environmental Qualification Resolution (RCA) and desert the project.

4.4.2 (Re)imagining a fieldwork in pandemic times

When the COVID-19 pandemic began, I had only been in my doctoral program for five months. Throughout 2020, I worked on the literature review and other writing for my doctorate while living under the health restrictions in the UK, including lockdowns in Cambridge. Emotionally, that whole period was very demanding and unsettling. I had no certainty about whether my fieldwork would be possible or not. Between April and August, flights to Chile were restricted or cancelled. Indeed, the borders were closed for a period and the only options available were humanitarian or emergency flights. In my case, these did not apply.

However, in November 2020, the situation improved as the number of deaths and infected cases decreased. I finally arrived in Chile on the 10th of November 2020. I had 14 days of self-isolation in Santiago. During that period, I reimagined my fieldwork and after an on-line meeting carried out on the 20th of November with my main PhD supervisor, I was able to make some decisions and to reimagine my doctoral project. In the context of the pandemic the only option was to imagine a scenario in Santiago and to consider only working with adults. Thus, I decided to move the focus of the project to initial teacher education, first considering the global pandemic, and secondly the possibility of carrying out fieldwork with a group of adults (pre-service teachers instead of high school students). These decisions were agreed with UCL's risk assessment and ethics committee. Considering that collaborative projects entail long-term relationships, I had in mind for the future to evaluate a second phase of the fieldwork with future secondary students of the teachers participating in the project. In this period of isolation, I started the process of recruiting participants by email.

4.4.3 Open invitation to collaborate to pre-service science teachers'

The initial phase involved an open invitation aimed at recruiting pre-service science teachers (university undergraduates in their last year) to participate in the collaborative project. My initial reason for inviting pre-service teachers was justified by the gap found in the literature about the lack of training and expertise of teachers for planning and developing outdoor science activities (Dillon, 2012; Glackin, 2015; Rickinson et al., 2004). Moreover, my rationale was to figure out and investigate what kind of challenges and opportunities we have in Chile, in terms of initial science teacher education. Furthermore, as a science teacher educator, I wanted to explore what are the pre-service teachers' *visions* about science and environmental literacies as a result of science education programmes at a public university in Chile. Since I have undertaken previous research about the contribution of collaborative and interdisciplinarity research in outdoor scenarios with postgraduate master's students (see Guerrero & Reiss, 2020), I also wanted to contribute to investigate opportunities to promote critical scientific and environmental approaches among science educators, particularly pre- and in-service science teachers.

The invitation was first extended through my personal connections and academic network at a public university in Santiago, Chile, with which I had collaborated between 2015 and 2018 in my former role as a physics and biophysics teacher and as a researcher for the Chilean Ministry of Education at university of Santiago. Two formal invitations were issued to the head of programmes that educate biology and chemistry pre-service teachers, as well as the Pedagogy programme in physics and mathematics. Following a positive response from the head of the biology and chemistry department, in December 2021, I was remotely invited to present my PhD project and provide additional context about the invitation. During this presentation, I discussed the concept of fostering a collaborative initiative involving initially pre- and in-service science teachers and science educators from two Chilean universities. I presented the potential project's research objectives, highlighting explicitly the opportunities to rearrange and reorganise my own ideas according to the discussion in the collaborative group of participants. I also presented some preliminary potential research questions to examine the visions of pre-and in-service teachers concerning scientific and environmental literacy, along with the necessary knowledge for designing, planning, and conducting outdoor science activities from critical approaches.

Upon extending the project invitation, I received seven emails indicating interest in participation and contribution to my thesis. Finally, five of these seven university students agreed to participate in the project's inaugural meeting/interview. These initial interviews were conducted between January 2021 and April 2021. After the initial interview, four of the five agreed to continue working on the project.

4.4.4 Analysing data

I carried out five initial and four final interviews with pre-service teachers, posing a series of questions and conducting the analysis using reflexive thematic analysis based on Braun and Clarke (2023). This process began with familiarisation, where I first transcribed the interviews and read through the transcripts multiple times to deeply understand the content. In this process I took notes and added memos using NVivo software. During this phase, I also reflected on my initial impressions and potential biases, noting them to remain conscious of them throughout the analysis. Next, I generated initial codes by systematically identifying significant phrases and segments relevant to the research questions, keeping reflective notes alongside the codes to capture my thoughts and interpretations. Figure 5 provides an example of a piece of text analysed using NVivo. Following this analytical process, I searched for preliminary themes by examining the codes to identify patterns and overarching themes, engaging in reflexive thinking to consider how my perspectives might influence this process of identification. I then reviewed the codes and themes to ensure they accurately reflected the data, refining, combining, or discarding them as necessary and revisiting my reflective notes to address (and recognise) any biases. Once finalised, I defined, described and named each code and theme, summarising their essence and selecting representative quotes from the interviews, while considering how each theme related to the broader context of the thesis and existing literature reviewed mainly in Chapters 2 and 3. The final step involved writing up the analysis into a coherent narrative, integrating the themes and supporting them with evidence from the data. Throughout this process, I maintained a reflective stance, continuously questioning how my interpretations aligned with the data and considering alternative viewpoints. By incorporating reflective practices throughout the thematic analysis, I ensured a deeper, more nuanced understanding of the experiences particularly of pre-service teachers and also all other participants, acknowledging, recognising, and reflecting on the influence of my own biases and perspectives. The codes and set of questions I asked during the interviews with pre-service teachers will be described throughout Chapters 5 and 6 in a descriptive way.

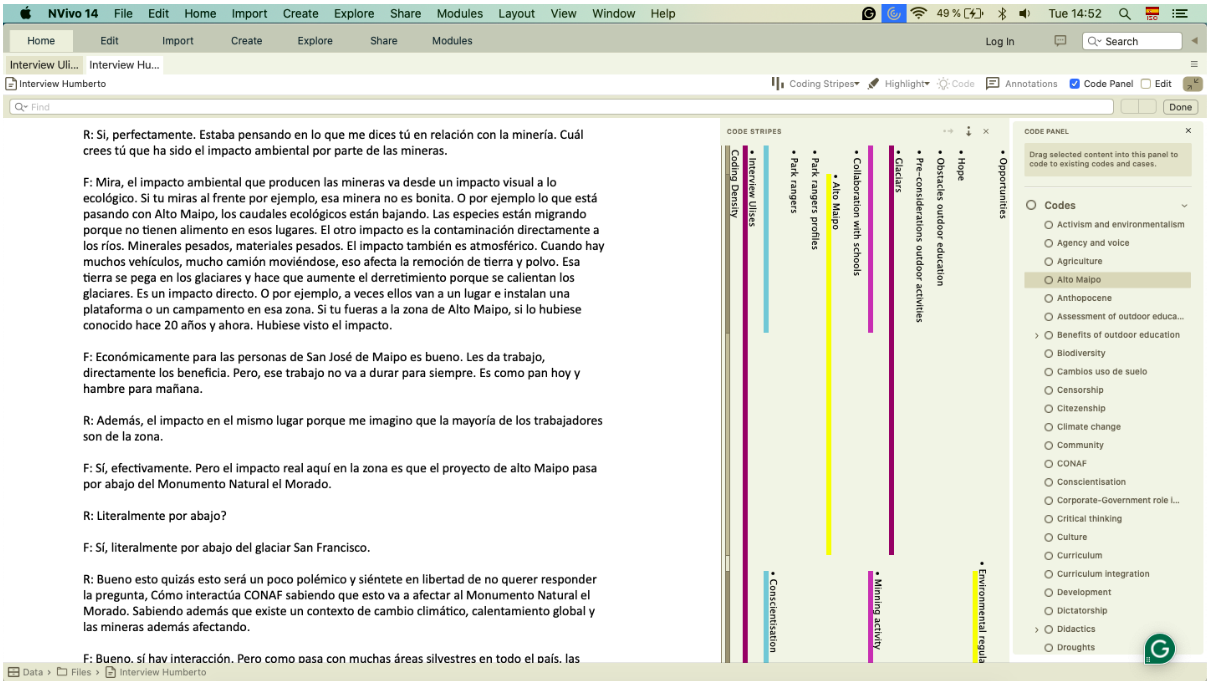

Figure 5. Data analysis with NVivo 14 and the associated list of codes.

4.4.5 Critical document and policy analysis

I also analysed several documents, described in Table 2, in the same NVivo project, utilising a combination of reflexive thematic analysis and critical discourse analysis, in a similar way as I did in Guerrero and Torres-Olave (2022), described also in Chapter 2. This process began with familiarisation, where I thoroughly read and re-read the documents to deeply understand their content. During this phase, I reflected on my initial impressions and potential biases, noting them to remain conscious of key ideas throughout the analysis. Next, I generated initial codes by systematically identifying significant phrases and segments relevant to the research questions. Each segment was labelled to capture its essence, and reflective notes were kept alongside the codes to document my thoughts and interpretations. Following this, I searched for themes by examining the codes to identify patterns and overarching themes that applied across all data sources, engaging in reflexive thinking to consider how my perspective might influence theme identification. Incorporating critical discourse analysis, I then examined the language used in the documents to uncover underlying power dynamics, ideologies, and assumptions. This involved analysing the choice of words, phrases, and structures to understand how they shaped the representation of topics and issues. Throughout this process, I questioned how my own background and perspective might influence my interpretations and sought to remain critically aware of these influences. After identifying potential themes, I reviewed them to ensure they accurately reflected the data. This step involved refining, combining, or discarding themes as necessary, and revisiting my reflective notes to address any biases. I also examined the discourse elements to understand how they interacted with the identified themes, providing a richer context for the analysis. Once the themes and discourse elements were finalised, I defined and named each theme, summarising its essence and selecting representative excerpts from the documents to discuss and enrich my analysis. I considered how each theme related to the broader context of the study and existing literature, ensuring a comprehensive understanding of the content. The final step involved writing up the analysis into a coherent narrative, integrating the themes and supporting them with evidence from the documents. Throughout this process, I maintained a reflective stance, continuously questioning how my interpretations aligned with the data and considering alternative viewpoints. By combining reflective thematic analysis with critical discourse analysis, I ensured a deeper, more nuanced understanding of the documents, acknowledging and mitigating the influence of my own biases and perspectives.

Table 2. List of documents analysed.

Institution in charge of policy document	**Name of document**	**Year**
Superintendency of Education, Ministry of Education.	*Guidelines and national regulation about outdoor education*	2019 and 2023

Center for Improvement, Experimentation and Pedagogical Research CPEIP, Ministry of Education	*Teacher Training Standards in science education in Chile*	2022
Ministry of Education	*Quality Assurance Law (Law 20129)*	2006
Ministry of Education	*Teacher Professional Development System (Law 20903)*	2019
National Forest Corporation (CONAF)	*Management Plan of natural Monument 'El Morado'*	2011
Chilean State	*National Constitution* *Proposal for National Constitution*	1980 2021

4.4.6 Open invitation to collaborate to in-service science teachers

I sent an invitation to in-service science teachers whom I felt might be inclined to participate on a collaborative project. This call was directed towards in-service science teachers, using a network of teachers who had taken part in projects led by the Ministry of Education and a public university in Santiago as well as teachers who had engaged in training workshops, postgraduate programmes, or other educational initiatives at the university. The main requirement was that teachers had experience in outdoor science education and more than ten years of teaching experience. Given the circumstances stemming from the COVID-19 pandemic in Chile, only five teachers responded to this call. Due to the project's nature, only two science teachers consented to participate. Those teachers were interviewed for the first time in March 2021. The data analysis process followed a similar process as presented in previous section.

4.4.7 Invitation to science educators from Chilean universities

The call to assemble science educators was once again facilitated through my academic network. Formal invitations were disseminated via social media to scholars from three Chilean universities: University of Santiago de Chile, University of Chile, and the Pontifical Catholic University of Chile. The criteria required educators to possess over ten years of experience in university teaching and scientific training, whether in biology, chemistry, physics, or related fields, and to teach courses that prepared future science teachers.

As a result of this call, two academics agreed to participate in the initial round of interviews. The first science educator was a male ecologist with over 20 years of experience in scientific research and more than ten years involvement in initial science teacher education in a public Chilean university in Santiago. The second science educator who agreed to participate and collaborate in the project was a female biology researcher with expertise in teacher education within didactics and science education fields. She had been working for more than 15 years in in different professional development programs (e.g., Master and PhD programs in Didactics of Science) in a private University in Valparaíso (Valparaíso region) of Chile. The initial interviews with both science educators were carried out between March and April 2021. Afterwards, they both agreed to participate in dialogical seminars, focus groups and activities planned collaboratively. However, due to personal reasons, only one of them participated in all aspects of the project. Similarly, I codified and analysed data produced during focus groups and dialogical seminars based on the process presented in the 'Analysing data' section.

4.4.8 During fieldwork

In parallel with the recruitment process, and during the initial interviewing stage, I explained to the participants my intentions of carrying out a collaborative project based on socio-environmental conflicts. To agree on the potential scenario of the project, we discussed and undertook preliminary research about territorial conflicts affecting Chile, specifically in Santiago and Valparaiso. In doing so, I presented two online platforms with socio-environmental conflict data bases. We analysed each platform, looking for conflicts close to institutions where participants were living or working. This stage was part of the initial collaborative research process. The first platform was called 'Map of Socio-Environmental Conflicts in Chile' (https://mapaconflictos.indh.cl/) (INDH, 2024), see Figure 6.

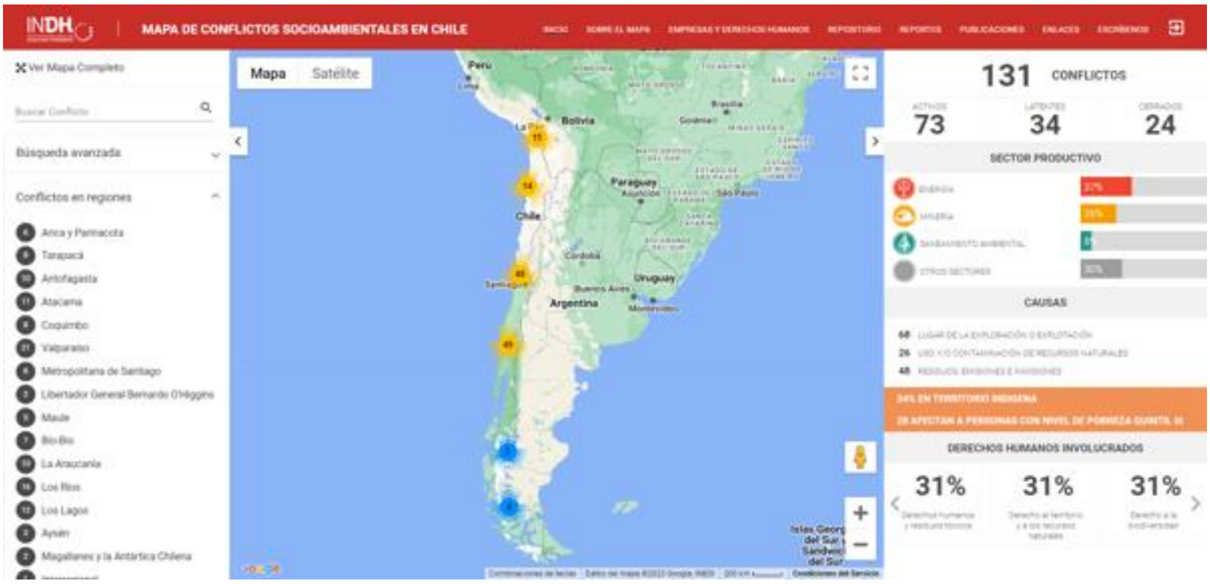

Figure 6. Map of socio-environmental conflicts in Chile developed by the Institute of Human Rights. The map shows the active, emergent, and closed conflicts in in each region of Chile. It also shows sectors and human rights involved in the conflicts.

This platform was developed by a public institution in Chile, the National Institute of Human Rights (INDH) in 2012. Unlike other public institutions, the INDH is not under the authority of the Executive (President of the Republic), Legislative (National Congress), or Judicial (Courts of Justice). Although it is financed with public funds, it is autonomous and independent. The map shows – as of August 2023 – 131 socioenvironmental conflicts in Chile (73 active, 34 emergent and 24 closed). This number was 116 in August 2020.

The platform gathers information that allows descriptions of the circumstances in which the conflicts were triggered, the parties involved, the territories where they occur, any infringements of human rights, and changes over time. In addition, the map offers general characteristics of a socio-environmental conflict, typically related to an investment project or a productive activity. According to the information gathered in the research process, this map provides: a) name or denomination given socially to conflicts that generate controversies, by the actors involved or media; b) a summary of the development of conflicts, based on public sources and the information provided by the actors involved, from the first record of public actions to date; c) the date at which the first public milestone of the conflict took place; d) the causes and reasons why, according to the actors involved, the socio-environmental conflict was triggered; e) information on the type of waste or emissions; f) information on the use or contamination of 'natural resources'; g) the latest status, indicating the condition of the socio-environmental conflict, according to the background information collected. The socio-environmental conflicts are classified into three possible states: Active – the socioenvironmental conflict has started, there are means of verification that account for new milestones that have occurred in the last year, and there are no records of its closure; Emergent – the socio-environmental conflict has begun, the last available means of verification are more than a year old, and there are no records that allow it to be closed; Closed – there is an agreement between the parties in dispute or an institutional resolution that has ended the socio-environmental conflict.

At this stage of the project, I also wanted to find information about the network of actors involved, including institutions and global interest corporates implicated in the selected socio-environmental conflict. Usefully, the platform also shows related actors. Besides, the map indicates natural persons[1], social organisations, NGOs, public and private companies, political actors, and State departments that have taken part or have been invoked by an actor involved in the public actions developed in the context of the conflict. To reveal links between actors and disputes, conflicts have been classified into two groups: territorial and strategic. Territorial conflicts relate to parties that face each other directly in the dispute, mainly due to their link or anchorage to places where it is located. Strategic conflicts correspond to actors who, without necessarily having a link with territories where the conflict is located, exert influence on the course that it takes. The platform also indicates human rights issues associated with various dimensions of a socio-environmental conflict and provides information about involvement of indigenous lands or territories (INDH, 2024).

A second platform I used to show and discuss information about socio-environmental conflicts was 'The Global Environmental Justice Atlas' (EJ Atlas) (Temper et al., 2015). The EJ Atlas consists of a collaborative map that classifies more than 3,000 crowdsourced conflicts around environmental issues that are currently occurring worldwide (see Figure 7).

[1] A natural person is a living human being. Legal systems can attach rights and duties to natural persons without their express consent. The concept of a natural person appears in business law and bankruptcy law, where it provides a contrast with an artificial person or a legal person which is an entity that is treated as a person for legal purposes.

Figure 7. Global Atlas of Environmental Justice, also known as EJ Atlas, is a website that documents environmental conflicts around the world.

Although the platform does not provide explicit information about power relations in its development process, it might be considered as a European initiative using geo-spatial information. For some authors, this EJ Atlas is a well-thought-out new spatial media presenting critical cartography, based on participatory research and activist-based knowledge (Elwood & Leszczynski, 2012).

The EJ Atlas appears as a tool for activists, civic, grassroots, indigenous communities, and scholars to leverage web-based geographic information technologies in their research and in their efforts to effect social change. The EJ Atlas collects stories from communities struggling for environmental justice and mobilises action. These environmental conflicts usually arise from structural inequalities of income and power and are often part of or lead to more significant gender, class, caste, and ethnic struggles. Furthermore, the EJ Atlas aims to make mobilisations more visible, highlighting claims and testimonies and making the case for proper corporate and state accountability for injustices inflicted through their activities. It also attempts to serve as a virtual space for those working on EJ issues to get information, increasing the visibility of environmental conflicts (Temper et al., 2015). Finally, by cataloguing conflicts, the platform also operates as a network that might be useful for teaching, exchanging ideas, and advocacy based on local and global socio-environmental conflicts.

The EJ Atlas documents social conflict related to claims against perceived negative social or environmental impacts. Dimensions of environmental justice include disputes over burdens of pollution and access to environmental resources, the right to participate in decision-making, and recognition of alternate worldviews and understanding of development.

Some helpful information from this platform is the action repertoires included on the website, such as formal claim-making, petitions, meetings, demonstrations, boycotts, strikes, legal actions, civil disobedience, collective violence, international campaigns, and other active forms.

After analysing collaboratively the platforms, and after identifying potential socio-environmental conflicts – as a possible scenario for a science outdoor education activity with the participants– I also assessed the potential risks with my supervisor, and I proposed some feasible and potential locations to carry out an outdoor science activity. I finally offered only some potential location options in Santiago. This decision was based on COVID-19 mobility restrictions in Chile. In this period, the Chilean government implemented a new system based on three different 'alert level phases': Alert Level 1, Level 2 and Level 3. These phases correlate with Low, Medium and High Health impact, depending on the number of total and new cases, deaths per day, mortality and recovery rates, and current active cases, among others. Rules regarding free mobility within the country changed specifically for each region and depending on different alert levels in the *comuna* (municipality). This system of alert level phases affected my whole fieldwork period in Santiago.

4.4.9 A first visit to the Natural Monument 'El Morado'

The place selected and agreed with all members of the project was a National Park called Natural Monument 'El Morado' (El Morado, hereafter) (see Figure 8a). El Morado is open to the public and visited by about 15,000 people each year, including several schools from all over the region. The park is located at San José de Maipo, Cajón del Maipo, Santiago, capital of Chile (see Figure 8b). The natural monument is a glacial cirque, part of the El Volcán River basin. The mountain El Morado has a height of 4,674 metres, dominating this protected area's landscape in the Andes Mountains (Segovia, 2014). Furthermore, El Morado is home to the San Francisco Glacier as can be seen in Figure 9a next to Lagoon El Morado (see Figure 9b). This glacier, and two more, provide 80% of the water supply in Santiago (Segovia, 2014). According to both platforms presented in the last section, El Morado is the site of an environmental conflict concerned with a hydroelectric power station project called

Alto Maipo. In the following section, I will explain in detail what this conflict is about in Chapter 6, using information provided and gathered by the platforms of INDH and EJ Atlas and a critical policy document analysis.

Figure 8a Entrance and welcome to ‘El Morado’. Figure 8b. El Morado is a glacial cirque and is part of the El Volcán River basin in the Quebrada Morales valley. (Source: Gonzalo Guerrero)

Figure 9a. Lagoon El Morado at the end of the trekking trail.

Figure 9b. San Francisco Glacier is a glacier in El Morado, a Natural Park located 100 km from Santiago, Chile. (Source: Blacklights)

On December 4, 2020, I had the opportunity to visit El Morado for the first time. The entire trekking trail to the glacier was closed to the general public due to COVID-19 health restrictions in Chile. However, I had authorisation from UCL and from the park rangers to cover the first six km of the trail, reaching 1,250 m above sea level. I was immediately impressed at the view from the small office of the park rangers (see Figure 10).

Figure 10. Entrance to the Natural Monument and view from park rangers' offices of the 'Morales' river.

On that day, I captured images and videos with my camera of the landscapes and the diverse local flora and fauna, primarily birds. My primary intention was to collect some postcards to share later with the project participants, motivating them for a group field trip; I also wanted to carry out pilot research by imagining a potential visit with a group of teachers. Besides, I wanted to assess some potential risks or difficulties.

Looking at my field diaries and the images today, I vividly remember how the entire landscape was always accompanied by the sounds and songs of the local and endemic birds of the Andes. I recall the path being lush with greenery, and the river dividing both sides of the Natural Monument (see Figure 11). I was astonished by the impressive diversity of colours in the mountains and the contrast with the snow which was scarce due to the summer and the hot temperatures (see Figure 12). During my two and half hours of trekking, I could identify a *remolinero araucana* or *churrete* and some other species such as *chincoles*, *jilgueros* (similar to *goldfinches*) and *mineros cordilleranos*, distinctive birds of the Andes mountains in Chile. As I reached the final part of the route, a friendly *cometocinos* (see Figure 13) approached me, presumably accustomed to peaceful human presence.

Figure 11. Panoramic view of the mountains surrounding El Morado. The distinct mineral composition and colours of these mountains have developed as a result of the effects of weathering, and the accumulation of sedimentary deposits over an extended period.

Figure 12. View of the peak of El Morado and the Morales river.

Figure 13. *Cometocinos* or grey-hooded sierra finch. *Cometocinos* belongs to the Thraupidae family and is native to Argentina and Chile. It inhabits natural environments of subtropical or tropical dry shrubland, as well as subtropical or tropical high-altitude shrubland in these regions.

4.4.10 Invitation to park rangers to collaborate

At the end of my initial visit, I approached one of the park rangers to express my gratitude and share my intentions of organising a collaborative pedagogical outdoor activity with science teachers and scientists, as part of my PhD project. I explained that the primary objective was to enhance the expertise of pre- and in-service teachers in outdoor education and, as a secondary aim, to investigate the extent to which critical scientific and environmental literacies can be promoted through outdoor science education. I openly discussed my intention to explore the impact of Alto Maipo in El Morado and also in the local area.

The park ranger expressed a keen interest in participating but noted the necessity of asking permission and formalising the arrangements with the institution responsible for the park and obtaining the required administrative permits. He also enthusiastically discussed the park's flora and fauna and elaborated on his role as an environmental educator. He informed me that the park receives daily visits from teachers and students from across Chile and expressed a strong interest in enhancing his work with the general public and with school teachers and students. Due to his interest, we concluded our initial informal conversation by discussing the potential involvement of two park rangers in the project.

After sending some emails and obtaining permission from the Chilean National Forest Corporation (CONAF), the authority in charge of the park, I formalised the necessary authorisation to carry out my project. I also formalised the participation of the two park rangers in the collaborative project. I contacted them and I started the first interviews with them in February 2021. A similar process – based on reflective thematic analysis – was followed for the analysis of their interviews.

4.4.11 Summary of the final group of participants and collaborative research methods

Finally, after all the initial stages and recruitment process, 10 participants were willing to embark on a collaborative project. Table 3 summarises information about participants' pseudonyms, roles, disciplines/expertise, demographics and experience.

Table 3. Final group of participants in collaborative research project

Pseudonym	Role	Years of experience	Discipline of expertise	Institution
Andrés	Park Ranger	25	Agronomy	Public institution – El Morado

Humberto	Park Ranger	20	Agronomy and environmental education	Public institution – El Morado
Ursula	Scientist – Science educator at university level	15	Biology and Didactics of Science	Private university
Rubén	Scientist – Science educator at university level	20	Ecology and biology	Public university
Clara	In-service science teacher primary and secondary level	20	Natural Sciences	Public school
María	In-service science teacher primary and secondary level	10	Natural Sciences	Public school
Andrea	Pre-service science teacher	-	Biology and chemistry	Public university
Angelica	Pre-service science teacher	-	Biology and chemistry	Public university
Antonia	Pre-service science teacher	-	Biology and chemistry	Public university
Paulina	Pre-service science teacher	-	Biology and chemistry	Public university

With this initial group I officially started some collective meetings (dialogical seminars and focus groups) to discuss my research questions and also to raise other relevant topics for them. The qualitative methods are described in Figure 14.

I conducted a similar analysis on data from focus groups and dialogical seminars using reflective thematic analysis but also extending this analysis with critical discourse analysis.

Starting with familiarisation, I reviewed the transcriptions and noted any initial impressions and biases. I generated initial codes to identify key phrases and segments relevant to the research questions, maintaining reflective notes to capture my thoughts. Next, I identified themes by grouping related codes and engaging in reflexive thinking to understand the influence of my perspectives. Using critical discourse analysis, I examined the language used to uncover underlying power dynamics, ideologies, and assumptions. Themes were then reviewed and refined, addressing any potential biases through reflective notes. Once finalised, I defined and named each theme, summarising its essence with representative quotes from the sessions. The final write-up integrated these themes and discourse elements into a coherent narrative, supported by data from the focus groups and seminars. In Chapters 5 and 6, I will introduce some of the interview or focus group questions and topics I discussed with all participants at each of the stages. I will also explain, when appropriate, what we did in the dialogical seminars and on the fieldtrip and at each stage of the collaborative project. Finally, it is relevant to mention that all data analyses were undertaken in the original language (Spanish) and then for the purpose of writing, all relevant quotation were translated into English by myself.

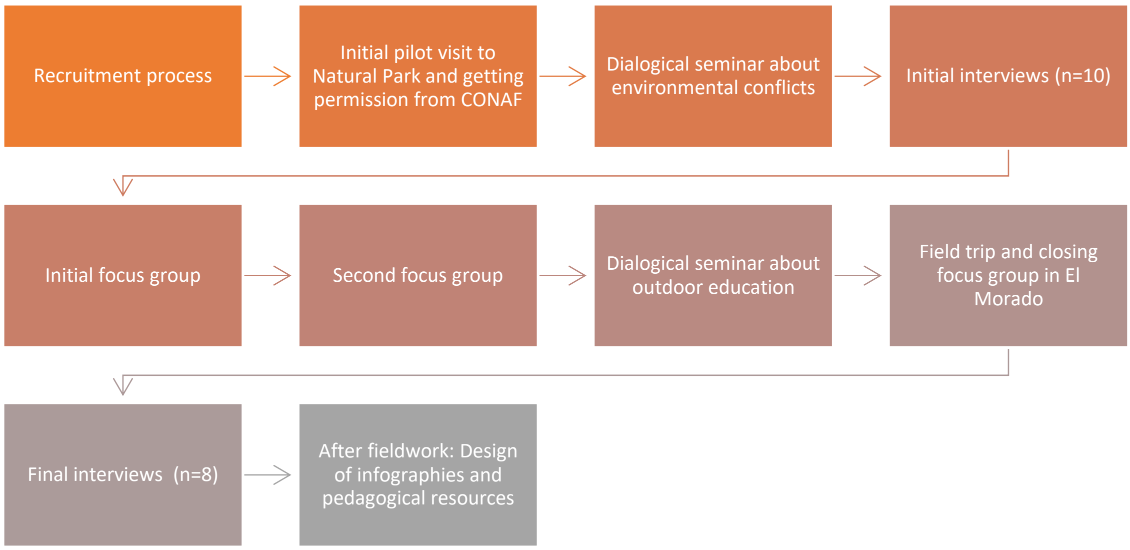

Figure 14. General stages of collaborative research and data production.

4.5 Ethics in collaborative research

Collaborative research raises a range of ethical questions that may be complex. I will particularly focus on challenges that I, as a doctoral student, had to navigate. On the one hand, collaborative research holds ethical promise. Through explicit commitment to the communities involved, it could be argued that collaboration can offer a means of going beyond the standard ethical commitment to *do no harm* and towards what Mannivannan (2022) describes as "the need to do good in research" (p. 73). Yet, as scholars such as Banks (2013) have explored in depth, collaboration in research also raises complex ethical questions that require us to think beyond typical institutional ethical requirements (cf. Aldridge, 2012; Bradbury-Jones et al., 2018; Groot et al., 2019; Hawkins, 2015; Thomas-Hughes, 2017; Vaughan, 2014; York et al., 2021). For instance, CPR requires one to think particularly carefully about anonymity, power dynamics, beneficence, boundary-setting, burdening participants, representation and research dissemination, amongst others (Banks et al., 2013; Guerrero & Fernández, 2020; Penuel et al., 2015; Cohen et al., 2018).

I do not intend to conduct an in-depth analysis of the ethics of collaborative and participatory research. However, I would like to discuss some examples of ethical issues I, as a doctoral student, engaged in CPR. First, collaborative research adds complexity to the notion of maintaining participant confidentiality and anonymity in ethics review processes, by inviting us to also consider how co-researchers may be credited (Cohen et al., 2018; Fine & Torre, 2021). University ethics review processes often prioritise participant anonymity and confidentiality. Therefore, possibilities for crediting co-researchers, while upholding confidentiality protocols, can seem limited or complex to navigate. Secondly, crediting co-researchers poses a particular challenge for the ethical integrity of doctoral students, as PhD theses are typically sole-authored. Therefore, in my case as a doctoral student, I retain credit for producing knowledge, contributing to implicit epistemic extractivism in academia (Patricio & Santos, 2019). The receipt of a doctorate at the end of the process raises the question, ethically, what it means for co-researchers to benefit from the research. Navigating these challenges requires thoughtful approaches to acknowledging and transparently communicating researcher positionality (Brown, 2022). This process should be transparent and fully clear from the beginning of the CPR process. Thirdly, collaborative research raises a significant ethical conundrum in terms of planning and ethics-in-relation: what degree of participation, or collaboration, is ethically desirable? Brown (2022) suggests that we should not, ethically, "aim for fully egalitarian research, as we need to retain responsibility for researcher wellbeing" (p.208). Chilisa (2012) also highlights the flaw in assuming that increasing participation alone will necessarily lead to positive outcomes for communities. Anonymity, beneficence, and degrees of participation are a selection of examples of complex ethical issues to navigate in collaborative research.

We managed and resolved some of the tensions by fostering open communication and building a shared understanding of goals, roles, and expectations among all participants. To address power dynamics, I ensured, as much as I could, equal decision-making opportunities, making sure every voice was valued and heard. I prioritised beneficence by focusing on research outcomes that directly benefited participants. For instance, during the focus groups we discussed openly and transparently about expectations and potential benefits for teachers, science educators and park rangers in each of their institutions and daily routines. We established organically clear boundaries to respect participants' autonomy and privacy, which helped maintain mutual trust. For inclusive representation, I actively involved pre-service teachers' voices throughout the research process, ensuring their perspectives were integral to shaping both the research and its dissemination. I also maintained transparency in sharing findings, collaborating on co-authorship, and promoting a sense of 'community' ownership of the results.

4.6 My own process of conscientisation as a researcher

Throughout the project, and particularly during my fieldwork, my journey to becoming a researcher was deeply intertwined with my own process of conscientisation. My understanding of nature, especially my understanding about the interdependence with hydrological systems, changed significantly when I visited El Morado National Park with the park rangers. Initially, I had not considered how mining and other extractivist activities in the Andes directly impacted Santiago's water supply. For instance, understanding the role of glaciers in sustaining rivers triggered a profound shift in my perspective about the false human-nature dichotomy, sparking a new critical awareness of environmental systems.

As I examined environmental and hydrological issues further, I realised that regulations designed from an anthropocentric perspective were failing to protect these systems, allowing for the systematic inappropriate exploitation of natural 'resources'. This marked a critical moment in my understanding of how human-centric policies contribute to environmental degradation. My conscientisation took a more radical turn as I investigated the neoliberalisation of nature, where corporate interests and profit-driven agendas exploit natural systems at the expense of ecological and social sustainability (Villavicencio, 2021). This led me as a researcher to critically question power structures and the role of corporations in socio-environmental conflicts, as illustrated in the case of Alto Maipo.

This process not only led me to reflect on systems of oppression and inequality but also made me aware of my role as a teacher-researcher. I began to see research as a tool to challenge and transform these power dynamics, fostering collective action for environmental justice. Working collaboratively with pre- and in-service teachers, scientists, and park rangers further enriched my understanding and provided diverse perspectives on how we can drive change through education. This experience connected me further to the socio-political turn in science education research, where scientific literacy is intertwined with activism, leading to a more transformative approach to climate action.

Chapter 5. Collaboration and pre-service expertise in outdoor education

This chapter aims to answer the second research question of this thesis: How does collaboration enhance the expertise of pre-service teachers in outdoor education? In doing so, the findings in the following pages contrast the evolving discourses and themes identified during initial interviews, two focus groups, two dialogical seminars, and final interviews conducted after planning – collaboratively – and visiting El Morado National Park.

In the first part, 'Previous experiences and declared expertise', I discuss previous experiences of pre-service teachers in university-level outdoor education. I present representative excerpts from pre-service teachers' interviews, which were analysed through a reflexive thematic analysis (RTA) process (Braun & Clarke, 2023) described in Chapter 4. This primary section critically discusses their previous experiences and declared expertise during their teacher education. During initial interviews, I also contrast pre-service teachers' experience with insights supplemented by science educators to understand an apparent 'lack of expertise'. In doing so, I also included critical policy analysis, adapting some stages of discourse analysis by Fairclough and Fairclough (2013) as I also showed in Chapter 2. For this chapter, this type of analysis is particularly helpful in providing structural explanations about institutional practices, how knowledge is constructed, and how some educational perspectives are included or excluded during outdoor science teacher training activities. This analytical process seeks to understand and explain the experiences narrated by both groups of participants but with a focus on pre-service science teachers. Specifically, I discuss how some perspectives of scientific and environmental literacies might promote certain types of expertise in outdoor education at the expense of others. In Chapter 6, I examine in depth how outdoor education can support critical approaches for scientific and environmental literacies through dialogue between different actors.

The second part, 'Learning together', examines the interactions and dialogues among all participants – including park rangers' voices – during the focus groups and dialogical seminars. The latter was led by a researcher experienced in science outdoor education Prof. Michael Reiss. Focus groups and dialogical seminars allowed me to investigate social and symbolic representations of outdoor education from different perspectives and identities. I present quotes from dialogues that encapsulate themes which show why teachers follow certain narratives. Examples and evidence of how dialogue and collaboration could effectively enhance the expertise of pre-service teachers in outdoor education are discussed in this section.

Finally, in the third and final part, ‘Influence of collaboration on pre-services teacher outdoor education expertise’, I discuss the findings from final interviews conducted after collaboratively organising an outdoor activity and visiting ‘El Morado’. In this section, I provide explicit evidence about how discourses around expertise among pre-service teachers were reinforced through collaborative research and by visiting the park. The main themes identified from the interviews and focus groups on each stage of RTA are presented in Table 3.

The themes in Table 4 were developed using a combination of inductive and deductive approaches. Initially, I conducted an inductive thematic analysis of the interviews and focus groups, allowing themes to emerge directly from the data. This was a reflective process, where I repeatedly identified patterns and meanings in the participants’ responses. After identifying initial themes, I connected them to the main topics that had emerged from my systematic literature review. This process ensured that the themes reflected both the participants’ experiences and existing scholarly discussions on the topic.

Table 4. Stages of the research and themes that emerged from the reflexive thematic analysis.

Stages	***Theme***	***Codes***	***Description***
Initial interviews	Previous experiences and declared expertise	Content of outdoor activities	Subjects and materials covered in outdoor education programs.
		Focus of outdoor activities	Explicit and implicit mentions to main goals and objectives of outdoor education activities
		Visions of scientific or environmental literacies	Understanding and perspectives on scientific and environmental literacies based on *visions* framework described in Chapter 2.
		Outdoor education training	Preparation or training teacher education pre-service teachers received related to outdoor education methods and practices.
		Relevance or benefits of outdoor experiences	Significance and positive impacts of outdoor education on students and teachers.
		Pre-service teacher confidence	Explicit mentions about self-assurance and readiness of pre-service teachers to conduct outdoor education activities.
		Planning tools	Previous resources and strategies used by pre- and in-service teachers to organise and plan outdoor education activities.

		Didactic approaches	Implicit or explicit teaching methods and strategies used in outdoor education.
		Guidelines and assessment for outdoor education	Standards and criteria for evaluating outdoor education activities.
		Connection with nature	Relationships and engagements with natural environment fostered through outdoor education.
		Reality or real world	‘Reality’, practical, ‘real-life’ context or applications of outdoor education activities.
Initial and final interviews	The potential of the geographical area of ‘El Morado’ for promoting critical science and environmental literacies	Geographical context of ‘El Morado’	Explicit or implicit mentions to the interconnected hydrological system and particular geographical context of El Morado.
During whole process		Observation and emotional connection with nature	Relevance of observing and connecting with nature.
During whole process		Dialectics of nature	Explicit and implicit mentions about human-nature relationships.
During whole process		Interdisciplinarity	Implicit or explicit mentions to. Developing interdisciplinarity through outdoor education in general and particularly at visiting El Morado.
Focus groups and	Learning together	Identities	Personal and professional identities of teachers and

dialogical seminars			how they relate to outdoor education.
		In-service teachers' outdoor experiences	Experiences and insights of teachers in outdoor education.
		Scientists' outdoor experiences	Experiences and perspectives of scientists involved in outdoor education.
		Obstacles of outdoor education	Challenges and barriers raised by participants at implementing outdoor education programs or carrying outdoor activities.
		Benefits of outdoor education	Challenges and barriers to implementing outdoor education programs.
		Dialogue	Relevance of conversations and discussions about outdoor education practices and theories.
		Approaches of outdoor education	Methodologies, didactic approaches and practices in outdoor education.
		Disconnection from nature	Issues related to the lack of engagement or connection with the natural environment.
During whole process	A monster in the park	Alto Maipo	Explicit or implicit mentions to Alto Maipo hydroelectric project
Visit to El Morado			

Final interviews	Influence of collaboration on pre-service teacher outdoor education expertise	Confidence	Potential boost in self-assurance gained through hands-on outdoor education experiences.
		Considerations for outdoor activities	Factors highlighted by pre-service teachers to take into account when planning and conducting outdoor education activities.
		Planning expertise	Skills and knowledge required to effectively plan outdoor education activities.
		Enhancement of confidence	Ways in which outdoor education can build or enhance teacher and student confidence.
		Pedagogical knowledge in outdoor contexts	Pedagogical and teaching knowledge and skills applied in outdoor settings.
		Curriculum	Content and structure of educational programs that include outdoor education.
		Opportunities	Potential for growth and development through outdoor education experiences.
		Interdisciplinary	Integration of multiple subjects and fields in outdoor education activities.

During whole process	A glacier as a more-than-human entity to develop conscientisation	Glaciers	Mentions about the role of the glacier to promote critical scientific and environmental literacies.

5.1 Previous experiences and declared expertise in outdoor education

In answering initial interview questions regarding previous outdoor experiences and declared expertise, all pre-service teachers mentioned having at least one experience – at the university level – related to outdoor science education. Most of these activities were confined to disciplinary subjects such as biology or ecology and were not integrated into subjects related to didactics, science, or environmental education. Overall, their experiences, such as visiting a park near the university campus during their initial teacher training, left various positive impressions.

In terms of previous experience with outdoor education, there was a common scarcity of opportunities for collaboration and a need for explicit pedagogical training on planning and carrying out activities outside the classroom. Indeed, five pre-service teachers interviewed described only one or two outdoor activities during their entire teacher training period. These limited experiences were narrowly focused on scientific facts, needing more pedagogical opportunities to connect with broader dimensions. To illustrate this point, I shall discuss a significant outdoor experience highlighted by Paulina, emphasising learning outcomes and conceptual knowledge about birds:

> [in my first outdoor activity] I remember learning to distinguish birds. There are two types of pigeons in the park; there are smaller and larger pigeons, but they have different names. Now [after the outdoor activity], I can recognise the birds at the university, and we know, at least, what the birds that surrounded us all day are called. (Paulina)

Paulina's learning experience can be analysed through the theoretical lenses of scientific and environmental literacies, as explored in Chapter 3. For example, the focus of this outdoor activity could be conceptualised within the foundational framework of environmental literacy and aligned closely with *Vision I* of scientific literacy while also extending marginally to *Vision II*. This extension connects knowledge about birds to everyday experiences, such as recognising birds on the campus. In a parallel manner, Angelica reflected on her learning from previous outdoor activities, highlighting a similar perspective:

> In the first year, we had one outdoor experience, well, actually, we had two in total [in her four years at university]. We first went to the university campus and created a scale model of the solar system in the backyard. In the second one, I also remember that the teacher explained how the essential thing about a pine tree was that it released a specific toxin so that none (...) no vegetation around it would grow (...). So, he was giving 'curious facts' and 'tips' related to Botany, so to speak, to Plant Biology. (Angelica)

Angelica's limited experiences once again highlight outdoor education's tendency to focus primarily on *Vision I* of scientific literacy. The educational objective of the outdoor activity was centred on understanding concepts, models, and intriguing or entertaining facts about elements in the park. However, in terms of societal connection and after asking more follow-up questions to Paulina and Angelica, both activities appeared to lack a direct link to societal issues. In my view, they failed to explore, for instance, how scientific knowledge of the solar system or plant biology could be pertinent to comprehending or addressing broader societal challenges, such as environmental conservation or biodiversity.

Regarding the potential integration with aspects related to critical approaches to literacies, none of the activities described by in-service teachers encompassed an investigation of ethical, economic, or political ramifications. For example, pine trees releasing toxins could serve as a starting point for discussing broader environmental concerns in Chile. Such concerns might include deforestation, the park's biodiversity, or the economic consequences of monoculture pine forestry practices in our country, which is a vast topic, as noted by Infante (2023). A discussion on the ecological role and impact of pine trees could foster a more holistic understanding of ecosystem dynamics and the human influence on nature, and an in-depth examination of environmental strategies of pine trees could prompt critical discussions on topics such as adaptation and survival, ecological ethics, and human intervention in natural processes. Similarly, an understanding of the solar system could be linked to debates on the funding of space exploration or the influence of science in shaping national policies.

Overall, pre-service teachers experienced a lack of outdoor education opportunities at the university level. When such opportunities arose, the pedagogical focus remained centred on individual activities, which were superficial and narrowly educational. These experiences, by being overly individualistic, overlooked the valuable opportunity to enhance the outdoor learning journey by integrating collaboration, dialogue, and critical discussion among pre-service teachers. Focusing on broader life dimensions could significantly enrich and invigorate the learning experience in outdoor activities.

5.1.1 Self-declared expertise: 'Scratching yourself with your own fingernails'

Based on the need for outdoor experiences at teacher training level, pre-service teachers articulated concerns about the absence of explicit pedagogical and didactic training for organising outdoor activities. They all highlighted the necessity of independently addressing this gap, foreseeing the need to rely on their acquired knowledge, skills, and resources to plan and execute these outdoor activities effectively. This reliance on self-directed learning emphasises a significant challenge in their professional development, underlining the need for more structured guidance in this area:

> I do not feel that there is a particular planning or training [at the University] and, ultimately, a personal reflection. In the end, you will have to 'scratch yourself with your own fingernails' (…) because certain things they teach us are [hesitantly]; I do not know if I would call them ineffective, but a lot is left out. (Paulina)

In the interview, Paulina expressed concerns regarding the scarcity of information and dedicated spaces for pedagogical training in outdoor education. This deficiency in opportunities leads her to anticipate that in the future, she will, as an individual and lonely teacher, have to compensate for this gap by independently addressing the planning of such activities. This perspective highlights some of the challenges educators face when they are required to self-navigate their professional development in specialised teaching areas (Berry, 2009).

The significance of collaboration in teacher education is underscored in the literature, with benefits extending to both students and teachers. Jefferson et al. (2023) links the loneliness felt by trainee teachers to disengagement from collaborative practices. This isolation can be attributed to missed opportunities for building connections, sharing interests, and engaging in discussions during initial teacher education. Research indicates loneliness correlates with adverse academic and career outcomes (Jefferson et al., 2023). Therefore, creating a collaborative environment is vital for alleviating loneliness, fostering a sense of community, and promoting well-being and professional growth.

According to the Chilean policies on outdoor education (MINEDUC, 2023), schools must create a flexible schedule incorporating at least one outdoor activity per semester (in Chile, there are two semesters per year). Furthermore, the schedule allows opportunities for additional emergent pedagogical field trips, accommodating the evolving needs of teachers throughout the academic year. Organising a pedagogical field trip is a complex process, typically linked to the curriculum's learning objectives and involves a multi-step bureaucratic procedure. The step-by-step process is outlined in the Chilean regulation as follows:

1. Teacher Proposal: A teacher [usually individually] proposes a pedagogical field trip, outlining its educational purpose.
2. Technical-Pedagogical Head Approval: The technical or pedagogical head of the subject department evaluates and authorises (or does not) the field trip, ensuring its coherence with the curriculum's learning objectives.
3. Coordinator Review: The school coordinator assesses the trip's relevance to school regulations, the school's educational project, and available financial resources.
4. Logistical Arrangements: The coordinator is responsible for organising transportation, securing tickets, making reservations, and handling administrative tasks.
5. General Inspector Responsibilities: The general inspector arranges for replacing teachers and educational assistants and processes parental authorisations.
6. Teacher's preparation: The teacher prepares pedagogical materials before and after the field trip.

According to this regulation, teachers must navigate administrative steps independently before organising activities outside the school. This process necessitates systematic organisation, which should be integrated into teacher training. Moreover, this requirement appears to be individual, presenting a contradiction with the competencies based on collaboration required by Chilean Law 20.093 regarding teacher development. Analysing this new policy critically, teachers must, indeed, engage in dialogue and reflection with each other and with other members of the educational community, identifying needs, determining the best ways to address them, sharing experiences, and making decisions with the primary objective of supporting student learning (Ministry of Education, 2023). In this context, outdoor activities are an excellent opportunity for interdisciplinary collaboration (see Guerrero & Reiss, 2020). However, teachers should receive training in the administrative planning of outdoor activities and the pedagogical tools necessary to execute such activities effectively.

Reflecting on this matter, with a degree of unease in certain instances, pre-service teachers point out the deficit in training for outdoor education, especially in areas about didactics of experimental sciences. For example, Antonia notes her lack of preparedness for independently organising outdoor activities and underscores the importance of a specialised didactic approach in such contexts:

> I do not feel prepared. In fact, these didactic courses, umm, are more pedagogical, yet they focus more on indoor classroom didactics, like how to conduct a teaching session inside the classroom. I have never been explicitly taught how to prepare for an outdoor activity. (Antonia)

Antonia highlighted a specific point concerning the disciplinary approach to didactics of science in Chile. While she acknowledges that the didactics enrich her pedagogical practice, she observes a lack of focus on science learning outside the classroom. In this respect, science didactics in Chile appear to be exclusively concentrated on educational processes that occur within the science classroom and in the same vein, mainly with a focus on scientific literacy based on *Vision I* or *Vision II* (Pérez et al., 2024). I will discuss this tension further in Chapter 6.

When asked about the role of science educators at the university in training pre-service teachers for future outdoor activities, students point out that there is a behaviourist/traditional model similar to that used in practical activities conducted in a science laboratory:

> My experience with activities outside the classroom was identical to laboratory activities; they [science educators] give us a guide and send us off to do an activity. It was pretty tedious, especially when they made us, especially when the only purpose was to count birds. (Paulina)

Angelica further noted that although teachers of related subjects expect their students to be 'didactic', the same science educators reveal in interviews that they typically adhere to an 'old-fashioned' approach in science. This results in pre-service teachers feeling underprepared to plan educational outdoor activities, attributable to the insufficient pedagogical training at the university level and the absence of practical examples from science educators:

> Something that catches my attention is that, for example, they [science educators] teach us how to be didactic or they ask for such and such a thing for the teachers, but if, for example, throughout our training, our teachers are also quite behaviourist and old-fashioned. (Angelica)

During the initial interviews, there was a focus on identifying barriers and attitudes that may discourage educators from extending learning beyond the classroom. A common theme from discussions with pre-service teachers was the legal intricacies and obstacles involved in organising and carrying out activities outside the classroom. For instance, Angelica pointed out:

> Now that we are in general didactics, oh my God, they [science educators] are going to kill me. I feel that they have not done it either. In fact, when someone asks, the response is always the same: that it should be done, but there are specific requirements and permissions, and there is a law that I do not know. (Angelica)

This experience is similar to what they had in school with their science teachers when asked about previous experiences related to activities outside the classroom:

> Actually, I remember that when I was at school, we also asked a teacher why we were not going out. (…) the teacher said there is a law now restricting outdoor activities, and I was like, really? (Angelica)

Upon reviewing the current policy documents regarding outdoor educational activities in Chile, as governed by the Superintendencia de Educación (Superintendency of Education, 2019), it becomes clear that there are indeed comprehensive 'legal' frameworks in place. However, these frameworks are explicitly recommendations designed to focus on safety and preventive measures. For instance, some Chilean outdoor activity policies mandate written parental consent, a detailed identification of responsible adults, and an appropriate adult-to-child ratio. Additionally, they specify guidelines for the safe transportation of students, including vehicle conditions and driver certifications. These regulations strive to ensure the well-being and safety of students in off-site educational settings. Thus, some concerns regarding legal barriers may be misconceived, potentially affecting the attitudes of in-service teachers and university science educators towards organising outdoor activities.

5.1.2 Group management and discipline

In response to a hypothetical scenario where she is asked to imagine starting work at a school next Monday, and the school head instructs her that her first assignment is to plan an outdoor activity in a national park, I asked Paulina about her readiness to undertake such a task. She responds by expressing her views on whether she feels prepared to plan an educational outdoor activity:

> No, not at all. I would be somewhat panicked, and I think I would ask for support, perhaps from my course leader, who is someone I can talk to more. I do not feel prepared, and I also feel quite inexperienced. If I had received that training, I would feel ready, or at least

> open to the idea of planning an outdoor activity. But as of now, if I were to go out on Monday to prepare one, I do not think it would go well. The kids might become wild [laughs]. It is possible that situations could escalate, maybe even dangerously. My concern is that I need to gain the skills to manage a group in an unstructured environment. In a classroom, there is a certain level of control – the students are seated, and there is an established order, somewhat a legacy of the dictatorship system. However, in an open scenario, no walls or physical boundaries help maintain discipline. (Paulina)

Group management outside the classroom concerns Paulina, given her lack of training and previous experience in such environments. However, the level of worry and apprehension she expresses is notable. She admits that she would feel panicked and concerned about potential student risks. In this context, discipline emerges as a crucial tool for group control in outdoor activities. It is particularly striking that Paulina references the disciplinary system inherited from Pinochet's dictatorship. Indeed, Pérez-Navarro and Zurita (2021) discuss how this regime instilled a certain level of discipline in Chilean schools, a result of transformations in the educational experiences of students and teachers following the new regulations designed and implemented by the civil-military dictatorship in Chile between 1973 and 1990.

Regarding the same topic about discipline and about what pre-service teachers think about leaving the classroom with the students and using these experiences for students to learn science, Antonia states the following:

> I find it super necessary [outdoor activities]. Well, this also includes preparing the outdoor activities properly, so that they are not only in a dispersed environment. It is not that they have to be fully disciplined, but sometimes they are taken as '*paseos'* [walks without a pedagogical purpose]. In fact, students usually call them 'paseos'. (Antonia)

Finally, Paulina identified potential opportunities to enhance expertise in pedagogical outdoor activities during teacher training. She suggests:

> I think the first outdoor pedagogical activity for a teacher lacking experience or expertise in planning such events should be straightforward. The objectives of the outdoor activity may not be fully met, as they may not know how to steer the event to achieve these goals effectively. However, it is also crucial to incorporate this aspect into teacher training.

From the initial interviews, it became evident that this group of pre-service teachers in Chile faces a significant gap in targeted pedagogical training for outdoor activities during their university education. This gap results in feelings of isolation, lack of collaborative opportunities, and a reliance on self-directed learning and personal resources, which ultimately hinder their professional growth in this area. The concerns voiced by Paulina and Antonia emphasise a shortage of training spaces and a lack of preparedness, pointing to a university curriculum that prioritises traditional indoor classroom methods over outdoor learning experiences.

This lack of training is particularly important for outdoor science education, where many pre-service teachers feel unprepared to plan and conduct activities outside the classroom effectively. The predominantly behaviourist approach in university science education further reinforces an individualistic mindset, limiting pre-service teachers' ability to adapt to the dynamic, less structured nature of outdoor learning environments. Moreover, at the university level, the vision of outdoor activities seems framed within Vision I of scientific literacy without critical approaches or connection with further dimensions of life. Thus, the integration of outdoor activities in the Chilean educational system is disadvantaged by complex legal and bureaucratic hurdles, which create additional barriers for teachers trying to implement these activities.

According to those challenges and concerns, as discussed in Chapter 2, the literature identifies several factors that enhance pre-service teacher expertise in outdoor education. These include teachers' concrete experiences in outdoor teaching and learning environments; previous knowledge about barriers, health and safety issues, time and financial constraints (and also legal regulations at school and national level); knowledge about bureaucratic education system; and formal recognition for outdoor learning in educational practices (Dijk-Wesselius et al., 2020; Fägerstam, 2013; Lindemann-Matthies & Knecht, 2011; Neville et al., 2022). The lack of opportunities at initial training level may contribute to the limited expertise in outdoor education of in-service teachers. Barrable and Lakin (2019) and Blenkinsop et al. (2016) have emphasised the impact of teachers' confidence as a barrier to regular and positive outdoor experiences and suggested that experienced outdoor educators possess pedagogical skills beneficial to mainstream educators seeking to broaden their pedagogical scope. Furthermore, research indicates that teachers' beliefs and proficiency influence the nature and degree of learning in experiential education when employing experiential learning methods (Glackin, 2016; Thomas, 2010). Neville et al. (2022) highlight a significant decrease in outdoor learning opportunities for school pupils due to a need for more teacher knowledge, confidence, and expertise in outdoor teaching and learning. Moffett (2011) supports this view, identifying teachers' lack of confidence and competence as pivotal factors limiting the provision of outdoor learning in schools. Thus, there is a combination of factors, including confidence-related barriers, lack of personal experience, and a reduction in outdoor learning opportunities due to insufficient teacher knowledge and confidence, underlying the need for more collaboration to enhance the expertise in outdoor education. Finally, and related to the next section, Lugg and Slattery's (2003) study notes the deficiency in personal outdoor experience among pre-service teachers could lead to a gap in their understanding of the natural world (Blatt & Patrick, 2014).

5.1.3 Expertise in outdoor education and a (dis)connection with the natural world

Commonly, the concept of 'expertise' in outdoor education is described in the literature as a combination of specialised pedagogical knowledge, skills, and competencies that educators need to effectively teach and facilitate learning experiences in outdoor sceneries (Beames, 2012). As discussed in the previous section and also in Chapter 2, this expertise covers a wide range of areas, including group management, specific outdoor pedagogical knowledge, practical outdoor skills in navigating and sustaining outdoor activities, safety management, and the capacity to promote personal and social development through outdoor experiences (Priest & Gass, 2015). However, in my view, and after analysing the first nine interviews, possessing what is termed 'expertise' – particularly in science or environmental outdoor education – requires a more profound understanding or awareness that extends beyond these traditional definitions. This initial expertise level should involve understanding how natural environments, with their visual, auditory, and olfactory stimuli, can evoke emotions and a sense of marvel akin to a child's fresh and explorative view of the world (Scott et al., 2022). Due to the lack of previous experiences highlighted by all pre-service teachers interviewed, I will first discuss this non-traditional level of expertise.

5.1.4 Going outside the classroom to see the 'real world'

> I remember it fondly to this day. I felt like a five-year-old rediscovering the world. I had been to that park millions of times, but I had never noticed, I do not know, the types of birds or the different songs they sang. During the visit, I learned where the birds lived; some lived in certain kinds of trees, and some did not mix with the others. I felt like I was discovering a different world. (Andrea)

In the previous extract and response to some initial interview questions about outdoor education at the university level, Andrea shared her limited experiences (just two) related to science outside the classroom. She viewed these through two distinct lenses: one filled with the innocence and wonder akin to a child's perspective, and the other as a metaphor for rediscovering the natural world. I carefully selected this interview excerpt because it represented a common and frequent code in the theme 'previous experiences of pre-service teachers' among the (scarce) experiences of pre-service teachers at the university level. Additionally, this memory resonated with my own experiences as a young student, prompting me to reflect on my process of achieving this level of expertise as a teacher. Writing this chapter, I remember my first out-of-school activity. I was five years old, and we visited a national park two hours from Santiago in Rancagua, VI region of Chile. I travelled by train for the first time in my life with my mother and some of my good friends from kindergarten. I was a bit anxious at the beginning, but I also remember vividly the amazing time on the train and the happiness when we left the school. I recently found some pictures of the visit to this natural park, and from my face, I can see how happy and excited I was that day visiting the park. Now, writing these lines, and similarly to Andrea, I also remember experiencing the outdoors with the wonder and innocence of a child. This 'feeling' is frequently associated with a sense of curiosity, enhanced well-being, and a renewed connection with nature (Braund & Reiss, 2004; Dowdell et al., 2011; Louv, 2008).

For Andrea, a pedagogical purpose when visiting the nearby park changed her perception of what she was seeing, hearing, and feeling. Although she had been in the park many times before, the visit organised by the science educators at the university triggered a 'new understanding of reality'. The visit to the park seems to have helped her develop or deepen a more meaningful relationship with nature, which, for some reason, was absent before. As outlined in Chapter 4, engaging in outdoor activities can significantly strengthen one's bond with nature. However, this starkly emphasises the noticeable disconnect between indoor environments and the natural world, underscoring a concerning dichotomy in human-nature relationships and disconnections between what is happening indoors and outdoors in science classrooms and about what is 'real' or not.

According to Beety et al. (2022), these disconnections might be influenced by many factors, including ideological beliefs, political interactions, sociocultural norms, and institutional structures, which either impede awareness or foster indifference towards human integration with nature. Notably, such disconnections are not static; they can be created and experienced across a spectrum ranging from individual to societal levels. In this case, it is valuable to analyse what is happening at the level of initial teacher education and national policies about outdoor education because, in the context of university education, indoor scientific and academic environments can unwittingly contribute to a degree of alienation from the natural world. In this regard, Ursula (science educator) highlights this issue in one of the interviews about outdoor education and teacher training:

> I believe that a substantial majority of the subjects we taught [at the university level], especially in the context of initial science teacher education, are detached from reality. They do not correspond with the students' lives, particularly in matters like connecting with nature. In this aspect, we, as science educators, often remain reticent. I consider this to be an error. It is quite troubling, as it indicates a profound disconnection with the natural world.

According to Ursula, there is a disconnection from reality and the natural world. Similarly, as highlighted by Andrea, there appears to be an ontological perspective on how science is taught at the university level – traditionally disconnected from students' lives. This perspective provides relevant insights into understanding the lack of previous outdoor experiences among pre-service teachers at this initial level of expertise. Additionally, it sheds light on how approaches in the didactics of science, along with other discourses guided by official normative documents related to teacher education in the field of natural sciences in Chile, as well as legal frameworks and state guidelines on science subjects, might be shaping social practices around certain visions of scientific and environmental literacies and scientific culture (see Pérez et al., 2024).

Reflecting on the idea of disconnections from nature, I realise that these disconnections go beyond a simple lack of awareness of our human identity within the material and non-material elements that make up nature (Beery et al., 2023). Critical theories on human-nature relationships make it clear that such disconnections are rooted in broader social and collective factors, involving institutional, socio-cultural, and power structures. Freire's (1979) work on education resonates with me here, as he points to the absence of conscientisation processes, which I see as a significant issue in education. This absence is particularly evident in the limited opportunities for outdoor education at the university level, especially within initial teacher training programmes.

I believe that this lack of outdoor learning may be connected to the existing non-critical perspectives of scientific and environmental literacies and particular ways of teaching science that reinforce a division between classroom science learning and the natural world. Ursula's observation about perceptions of reality adds to this, suggesting that what happens outside the classroom is often seen as more 'real' and tangible. This false dichotomy could distort how students and in-service science teachers experience and conceive reality. Therefore, I feel it is crucial to explore more deeply into the dimensions of connection and disconnection, examining which factors perpetuate them and how we can reshape educational science practices to bridge these gaps.

The point about connection with nature also emerged after critically analysing policy and regulatory documents about outdoor education from the Chilean Ministry of Education:

> Outdoor education and field trips favour the integral development of children, as they connect them with a real, concrete world in which they can increase or complement the knowledge achieved in the classroom. (MINEDUC, 2023)

Again, the idea of 'real' and concrete represents an example of how disconnection from nature might be socially constructed and has multiple, often contested meanings subject to much philosophical discussion, which I will discuss in the next chapter. From the interview with the ecologist collaborating on the project – who was one of the science educators for most in-service teachers participating in the project – there is a potential explanation for this disconnection and lack of outdoor experiences at the university level, which could also be affecting this first-level of expertise needed at the teacher education level:

> In my view, this disconnection from nature is linked to the model of education, particularly the model of doing science we practise today as scientists. For instance, ecology has been drifting away from fieldwork due to a push to increase productivity. This shift is due to work in computing, molecular analysis, or phylogenetic analysis. As a result, there is no need to go into the field to observe. You simply need someone to bring you the samples, process them, extract the DNA, analyse the sequences, compare them with other species, and see which are descendants of which and how certain traits have evolved. Thus, the naturalist perspective of science has been lost and is no longer translated to teacher education. (Rubén)
>
> I stopped doing fieldwork a while ago because it represents a cost in terms of productivity. This shift is not due to a lack of interest, but because the implementation

> model or the productive model of science is so compelling, I would say, dominant. (Rubén)

According to Kreimer (2006), Latin American and, particularly, Chilean scientists and researchers seek to compete on an equal footing with century-old research centres in the Northern Hemisphere despite the obvious differences in monetary resources, infrastructure, cultural capital, and the costs of technologies, among others. This competitive logic, fuelled year after year by the stagnation of funds for research and the increase in new researchers, pushes science professionals to become isolated individuals, highly specialised and alienated from nature. Reflecting on this, I find it troubling how the pressure to meet global benchmarks can erode more holistic approaches and alienate scientists from the natural world, which should be at the heart of their work. This disconnection weakens the potential for meaningful, nature-integrated research and education.

As discussed in Chapter 2, outdoor learning has many potential benefits. However, according to Kivirinanta (2023), teachers need to be trained to plan and carry out outdoor activities during their initial education. Moreover, we can see from the pre-service experiences during initial interviews that there also seems to be a requirement to develop the required awareness competencies to reconnect with the natural world, break a dichotomy between humans and nature, and reflect on why outdoor education is relevant.

5.2 Learning together and permitting the emergence of the other

In the focus group sessions, I explored a range of pertinent topics. This section will examine the main findings derived from these discussions, concentrating on five key topics that emerged from the reflexive thematic analysis process as central to enhancing expertise through collaboration. The codes related to this theme are: acknowledging identities as an initial step for collaboration; sharing knowledge and wisdom for outdoor education; advancing interdisciplinary collaboration; living in a bubble; broadening pedagogical perspectives; and fostering a community of practice and expertise. These codes collectively underscore the multifaceted impact of collaborative efforts on enriching the educational practices of pre-service teachers.

5.2.2 Acknowledging identities as an initial step for collaboration

The first focus group session was held on Friday, May 7th, 2021, lasting two hours, from 16:00 to 18:00. This meeting was organised after the individual interviews with the 11 participants, which provided valuable information to decide on questions and topics for the following meetings and data production. Considering the diversity of roles, the first focus group aimed to introduce the project and primarily focus on the participants' identities, roles, and biographies. Drawing from Freire's ideas discussed in Chapter 4, I conduct my analysis of collaboration by focusing on participants' interactions and dialogues and considering that education transcends mere knowledge sharing; it embodies a transformation process through coexistence and collaboration (Freire, 1970). Thus, acknowledging intersubjectivities while collaborating might facilitate the emergence of diverse perspectives, voices and expertise.

In my analysis, I discuss my findings through the lens of Dávila and Maturana (2021), who highlight the importance of dialogue in collaboration. They argue that letting go of prejudices and preconceived ideas is crucial for uncovering the true essence of each participant. This is because physical and metaphorical distances can often prevent the recognition of others and ourselves. They suggest that overcoming these barriers is critical to fostering genuine understanding and connection within collaborative efforts.

As a way to introduce the ethos of the project based on collaboration and my positionality as a researcher, I started the first focus group, after the initial presentation, consent information and welcome words, by describing the aim of the project as follows:

> Gonzalo: I want to start by saying that dialogue is the most valuable aspect of this project. To begin this collaborative endeavour, it is essential to recognise ourselves from our respective standpoints and understand that we are always in a position to learn. You may find yourself sometimes in unfamiliar roles and positions for this project. In collaborative research, however, being honest and humble about our limitations is paramount. For instance, I may have learned certain things from my role as a science teacher or as a PhD student living in London. However, there are several areas where my knowledge could be improved. I might be well-versed in classroom activities inside the science classroom. Still, I need to be more informed about teacher training processes or outdoor activities related to environmental education, which we aim to explore with you here today. We will hear diverse viewpoints collaboratively, and this session will be our first exercise. We will be learning together.

In this introduction and presentation to the focus group, I intended to make my positionality and reflexivity as a researcher explicit. Positionality and reflexivity are concepts discussed in detail in Chapter 4 and are widely acknowledged as an essential initial consideration when planning and conducting collaborative research (Wilson et al., 2022). Besides, with my introduction, I invited participants to engage in dialogue and think of collaboration as an opportunity to understand different perspectives from a humble position and learn about outdoor education from various voices in science and environmental education. Being open to the limitations of our knowledge and experiences can help foster interdisciplinary and cross-cultural collaborations (Palmer, 2023).

As an initial step, my intervention aimed to underscore explicitly the notion that understanding our identities and who we are can offer genuine opportunities to address collaborative processes. The concept of identity "holds significant relevance in teacher education, serving as a comprehensive framework for exploring teacher learning and development" (Avraamidou, 2014, p. 146). Moreover:

> by understanding the ways in which individuals develop their professional identity over the course of their careers, but especially during their training (or preservice year(s)) and first five years, school leaders and policy makers may be better able to develop support and training to address this retention challenge in a more personalised way. (Rushton & Reiss, 2021, p. 142)

In this context, I view identity as a means to enrich expertise, drawing from the insights of Leibowitz et al. (2014), who also illustrated the critical role of academic identity in fostering intersubjectivity within collaborative research. While my theoretical framework does not explicitly focus on identities, some of my findings or emergent theory from the date underscored the relevance of this concept when initiating a collaborative project. I consider it relevant to discuss this in the initial section.

From the findings of the focus groups, it can be noticed that there was a particular 'development' process of identities among pre-service teachers throughout the project. This progression can be understood as a 'learning trajectory' that integrates past experiences and future aspirations into negotiating the present (Wenger, 1998, p. 74). These learning experiences are shaped by social contexts, reflecting the environments in which academics operate and personal histories (Archer, 2000). The construction of academic identity signifies intellectual growth; it is a self-reflective endeavour encompassing a network of individual concerns, values, and aspirations against which events are evaluated and decisions are made (MacLure, 1993, p. 314).

I initiated the first focus group by posing two general questions about identities: 'Could you describe who you are?' and 'What role do you envision for yourself in this project?' The responses to these initial inquiries on identity played a pivotal role in fostering mutual understanding and establishing common ground for discussing collaboration and collaborative research. For example, Angelica began with a brief introduction about herself:

> My name is Angelica, and like the other pre-service teachers, I am in my fourth year. I have also started the practicum this semester. I am fully willing to participate and collaborate in this project, and just like everyone else here, I hope that something gratifying comes out of it that can help us as professionals.

Angelica initially positions her identity from her role as a student, specifically, as a student-teacher in training. Angelica mentions being in her final year and starting her practicum stage. She expresses her willingness to participate and collaborate in the project as an opportunity that will strengthen her professional development. She highlighted the mutual benefit of the project. However, like all pre-service teachers – in this first collective meeting – her identity is primarily addressed only from a professional-intellectual perspective. In contrast, and as a departure from the way other pre-service teachers responded, Ursula began by saying:

> I approached the question of identity from a more personal perspective, initially side-lining the professional aspect. However, I gravitated more towards personal aspects when reflecting on who I am in this project. For instance, I am a woman, I am a mother, I am a daughter, I am a good friend. So, it is fascinating to consider our diverse roles and identities. However, I also became curious to imagine what role each of us would play in this project. In a way, I want to know what I will learn from others.

Ursula distinguishes herself from other participants by stressing the necessity of engaging with the concept of identity from a perspective that transcends the purely academic, a viewpoint I deem invaluable for initiating collaborative and collective research projects. This stance is especially relevant within the critical frameworks of scientific and environmental literacies, as outlined by Calabrese-Barton et al. (2013) and Siry and Ziegler (2017), where identity surpasses academic accomplishments or professional roles to include personal attributes, values, attitudes, and beliefs that influence an individual's interaction with science. According to Archer et al. (2012), identities, akin to literacies in education, are moulded by a myriad of factors such as cultural background, class, socioeconomic status, gender, race, and personal experiences. Therefore, understanding and exploring identities within science education is essential for fostering inclusivity, diversity, and equitable learning opportunities. This understanding is also pivotal when initiating collaborative projects with pre-service teachers and experienced science educators, as it significantly shapes the initial perspectives regarding scientific and environmental literacies, a topic I discuss further in Chapter 6.

Ursula's proposition is pertinent to collaborative projects as the construction and development of identity involve mutual engagement and shared repertoires (Lave & Wenger, 1991). She expressed curiosity about each person's role in the project, demonstrating humility and a willingness to learn from pre-service teachers despite her extensive experience as a science educator. Wilson et al. (2022) suggest that participants in a collaborative project should reflect on their identities about expertise within a field or seniority in educational research. This approach was significant as a starting point for collaboration since the faces of pre-service teachers during the focus group changed immediately. Smiles appeared in the conversation, and the initial tension about asymmetrical profiles decreased.

Throughout the project, academic identity was fluid and dynamic, fostering supportive collaboration that allowed participants to position and reposition themselves over time. This initial phase of being self-conscious about our identities can significantly influence how collaborative educational research projects are planned and managed. Another crucial aspect is the need to acknowledge and value each person's contribution, although it may not always be possible to do so consistently. In this sense, the discussion about identities during the first focus group emphasised the importance of addressing intersubjective relations within the group and building participants' sense of belonging and expertise. This is relevant since while collaboration can enhance the relationship between identity and learning, it can also lead to feelings of marginalisation or conflict. As Wenger (1998) noted, for example, feelings of comfort and discomfort are strongly linked to one's sense of expertise and contribution to a collaborative project. This point is particularly relevant for integrating pre-service teachers' voices and making them feel they are collaborating with these views and from their diverse identities. For instance, regarding my call for open dialogue and a humble stance, Tomas also made pre-service teachers feel more comfortable in the project by saying:

> I feel like a child in the classroom because I am learning a lot from others. When you ask me about identities, I imagine a mini biography. I want to say many things, but, in reality, time is limited, and for those of us who are older or have been working for a while, I think there is a lot of history.

Andrés found it challenging to share his life story concisely during the given time. As the group's most experienced member, with over 25 years as a park ranger, he struggled to encapsulate his vast knowledge and identity briefly. In my view, this difficulty served as a humble way for Andrés to express openness to learning from others following the introductions by pre-service teachers.

Humberto also added some deep and personal insights to the discussion about identities by saying:

> For me, identity is a personal matter that – in my humble view – also encompasses the spiritual dimension. The question of who you are in this research project is quite broad. One's relevance in this project can vary depending on specific criteria.

From this insight, I appreciate how Humberto's statement highlights identity as multifaceted and subjective, shaped by distinct characteristics and viewpoints. This perspective demonstrates an openness to learning from others and recognising the unique ways participants contribute to the project. Moreover, it aligns with the concept of conscientisation, as it calls for deeper awareness and critical reflection on how individuals' identities and experiences can enrich collective understanding and action.

The inaugural focus group session was a crucial starting point for our collaborative research project, laying the foundation for future engagement and dialogue among participants. Throughout the session, there was a notable emphasis on the significance of humility and openness in collaborative research, evident in participants' willingness to learn from each other and acknowledge their own limitations. A fundamental shift in perspective was advocated, urging us to move away from competition, towards fostering collaboration. Rather than prioritising personal desires, the focus was on embracing the ethos of sharing knowledge and resources. This shift signifies a departure from traditional notions of leadership towards collective inspiration and collaborative endeavours.

Following the interventions, students began feeling more at ease and were notably curious about learning from others. In the second part of the focus group, after personal introductions and initial discussions about identities, we shifted our focus to the project's objectives. As I said to the group:

> This first focus group aims to gather various opinions and perceptions on scientific and environmental education. Today, we are explicitly addressing the topic of outdoor education. The project seeks to link outdoor education with socioenvironmental

> conflicts, and we will explore this through collaborative and diverse lenses. Hence, it is essential to draw on your experiences, identities, and standpoints to understand the challenges and benefits of outdoor learning. This project will aim to adopt a collaborative, participatory approach, viewing education as a socio-community process. (Gonzalo)

I notice an initial and explicit emphasis on the value of collaboration. In this statement, I recognise my genuine motivation to start fostering a collaborative process for research in which all participants can bring their experiences about outdoor education and its connection to socio-environmental conflicts. I explicitly highlighted how collaboration enriches our understanding through diverse experiences and identities and I can also identify how these comments sought to foster conscientisation, as we collectively develop critical awareness of our social realities. My commitment in this focus group emphasises the belief that education is a communal process, where collective literacies are built through shared engagement. Actively involving everyone not only fosters shared ownership but also leverages collaboration to address challenges and uncover the advantages of outdoor learning, enhancing our collective capacity for critical reflection and action.

5.2.3 Enhancing expertise through dialogical seminars

Dialogical seminars are rooted in Freire's dialogic education (Freire, 1970), emphasising the recognition of knowledge, perspectives, identities, and experiences of all participants within the research project as fundamental in a collaborative process. After the first focus group, this seminar was a pivotal space for exchanging shared, contrasting, and co-constructed perspectives, enabling an exploration, challenge, and critique of the social world. A dialogical seminar is an educational approach that places discussion and dialogue at its core, particularly within collaborative projects. Participants engage in deep, meaningful conversations on specific subjects or issues, allowing for the exploration of diverse perspectives and cultivating critical thinking. In this project, dialogical seminars encouraged active participation, with participants collaboratively constructing knowledge about outdoor education through shared inquiry and reflection rather than passively receiving information from an instructor. These seminars foster an environment that values every participant's voice, fostering mutual respect and understanding. Following interviews and the first focus group, a dialogical seminar was held to discuss the opportunities and obstacles of outdoor education. This discussion was conducted collaboratively after a workshop facilitated by Prof. Michael Reiss.

During the pandemic, we agreed with the group to invite people with experience in outdoor education research. Prof. Michael Reiss kindly offered to facilitate an online seminar that could contribute to the dialogical seminar. The title of his presentation was: *Why undertake science field trips with school students?* In this seminar, Michael shared relevant elements that coincidentally aligned with some of the topics discussed in the focus group. For example, Michael commented on experiences in science laboratories as spaces for a simplified version of reality, which contributed to an in-depth discussion on this topic. Michael also presented the idea of what is 'real' when going outside the classroom and having an experience within the natural environment. The seminar explicitly mentioned the benefits of outdoor education and field trips based on the potential for student autonomy and opportunities to address interdisciplinary pedagogical field trips by integrating concepts and methodologies from different disciplines. Besides, Michael's ideas during the seminar were also about the relevance of place-based education, Actor-Network Theory (ANT) and new materialism. This idea about ANT was crucial to organise the discussion about the socioenvironmental conflicts around 'El Morado' (see Chapter 6). From this dialogical seminar, critical approaches for scientific and environmental literacies started to be part of our conversations about visiting 'El Morado'.

A topic that marked the focus of the first dialogical seminar was the significance of outdoor education to explore the multifaceted impacts and benefits of out-of-school activities, including cognitive, attitudinal, and values-based aspects, and the promotion of environmental empathy and interconnectedness between humans and nature. Participants discussed the need for increased resources, especially in underprivileged schools, and a critique of education systems that prioritise grades over comprehensive learning.

The dialogue started addressing the necessity of integrating interdisciplinary field trips into curricula. It advocated a shift towards experiential learning, emphasising learning's extension beyond traditional classroom confines to foster critical scientific literacy. The topic of activism was introduced and discussed collaboratively for the first time in this session by Antonia, who reflects on this point:

> I really enjoyed the part about decentralising education. The idea of decentralising education within individuals is also important because it is usually taught within the confines of classrooms, laboratories, and all, you know, very conceptual or very focused on the human being. So, it is also a good way to promote activism and to be

> critical about the environment, acknowledging that our actions have an impact and considering how to address those problems scientifically.

Following Antonia's intervention, pre-service teachers explored relevant discussions, mainly focusing on the complexity of the concept of 'reality' and the contrasting roles of outdoor activities and laboratory experiences. Angelica notably emphasised this point during the dialogical seminar and appreciated its significance. She initiated her intervention by raising important considerations about the value of taking students to laboratories and questioning what is 'real' or not in science education.

> Michael's workshop was excellent; it clarified a little more about the impact outdoor education has on students and its contribution to their teaching and learning process. However, a question arose for me: before taking children to laboratories, would it be necessary to first take them on activities outside the classroom as an initial approach to the natural phenomena surrounding them? This could help them later understand it, as you well said, as a simplified version of reality. Perhaps it might be much more critical, as a first step, to expose them to actual reality and then simplify it.

Angelica prompts reflection on the most effective and meaningful ways to engage children in learning about the world around them. This insight reflects a consideration of what constitutes the 'real' in learning science. Angelica suggested that the initial exposure to the complexities of nature, in its unaltered state, may provide a more authentic and foundational understanding for children. This suggestion contrasts with the idea of presenting a simplified version of reality in the classroom or laboratory, which I discussed previously during initial interviews in Section 1.

After this intervention, the group started to reflect on how to tackle this concept of reality and what we can do from didactics of science to plan activities which can ponder this approach. At that moment, the conversation shifted to what we can do to support a field trip effectively. The conversation now was mainly about the planning and preparation of didactic materials to provide contextualised 'supporting material' to the students who visit 'El Morado'.

In this regard, Andrés was very interested in knowing how to approach a pedagogical field trip:

> I would like to know if it is always good to have a specific guide for the students or to have a guide based on the students' current learning, perhaps allowing them to inquire

further with open questions when going out with the students whether to bring questions to a specific guide or to leave them open for further inquiry.

This is a crucial point in the dialogical seminar because, in my view, pre-service students realised how they could also have the knowledge to contribute to the role of environmental educators in ‘El Morado’. Pre-service teachers were very active after the park ranger’s concerns. Andrea questioned how science classrooms usually are based on a ‘banking model’, a term coined by Freire (1970), and with a great emphasis on grading students. She mentioned how, typically, the scientific contents have to be ‘absorbed’ by students. This approach can also happen in the park when visitors lack a pedagogical approach during field trips:

> I also considered that there is a significant emphasis on only grading here. For instance, I recently watched a video that highlighted how university admissions in Chile focus solely on exam scores, overlooking the student’s overall performance, acquired skills, and engagement or interests in specific subjects. So, I believe field trips based on traditional approaches might also treat students merely as passive recipients of knowledge, akin to ‘sponges’. This approach during field trips might restrict them in various ways by not allowing them to explore their interests or learn through inquiry. Therefore, I found this discussion intriguing, and attending this talk with him as the speaker was a valuable opportunity.

By criticising the education model in Chile, Andrea suggested that traditional educational approaches can be limiting, treating students merely as passive recipients of information rather than active participants in their learning process. Moreover, she commented on the value of outdoor education and the potential opportunities for assessment. She mentioned opportunities to reflect on open questions or to develop skills among students. I consider this to be a starting point to reflect about how collaboration can enhance reflections about the role of education and how outdoor education can also reproduce what is happening in the traditional science classroom, mimicking the ‘banking’ model of learning.

At the end of the dialogical seminar, resources arise as an obstacle. This is discussed by Clara, who comments:

> Public schools do not receive the same resources as private schools, which often belong to a higher social stratum. Therefore, my question pertains to your suggestions or

> recommendations for promoting these educational field trips in sectors or schools that may need more resources or funding.

This also arose from Andrés, who joined the conversation about resources:

> England has a history of science behind it, but here, in Chile, it seems complicated because there is no scientific culture, and research by scientists is hardly funded. Still, there should be a fund or a budget that includes science education, both to promote field trips and what we were talking about with laboratories because, in the end, we saw that we have to look for resources there, which can demotivate teachers.

The cultural differences between Chile and England make the discussion enjoyable, and Andrea is interested in this point from a curricular perspective. She now returns to the group's point about interdisciplinarity:

> Yes, well, regarding this cultural difference between both countries, I wondered if in England, there is something, some section, that requires schools to include educational field trips as mandatory and if these also mandatorily have to include interdisciplinary aspects (...) do they have to be interdisciplinary? That is my doubt, because here in Chile, at least, that does not happen.

The collaborative dynamics observed during the dialogical seminar, particularly the integration of diverse expertise and reflexive practices, played a crucial role in enhancing pre-service teachers' pedagogical skills and understanding. The seminar underscored the importance of acknowledging diverse perspectives and experiences. Encouraging active participation, this meeting fostered mutual respect and understanding. Pre-service teachers highlighted the significance of outdoor education, and environmental concerns and challenges within educational systems, such as resource disparities and traditional models, are acknowledged, with discussions on practical solutions and cultural differences between Chile and England. Participants advocated comprehensive learning experiences and suggested strategies to overcome obstacles, including promoting educational field trips from critical perspectives. This experience underscored the importance of interdisciplinary collaboration and community engagement in outdoor education, offering profound insights into how we can collectively work towards a more integrated and experiential approach to learning.

5.2.4 Sharing knowledge and wisdom for outdoor education

During the second focus group, park rangers and in-service teachers with extensive experience in organising outdoor activities, served as pivotal sources of knowledge transfer. This transfer of ‘wisdom’ highlights collaborative research and the critical role of collaboration in increasing outdoor education expertise among pre-service teachers.

Through discussions and dialogues, in-service teachers and park rangers emphasise how expertise beyond conventional indoor science education can significantly enhance students' learning experiences. In these two meetings, in-service teachers and park rangers presented – from their noteworthy experiences – a broader and more practical perspective on outdoor education. The dynamic interplay within the focus group involving park rangers illustrates how it initiated a profound reflexive process among pre-service teachers. I vividly recall the deep sense of fulfilment during our first and second meetings after navigating the challenging times of the COVID-19 pandemic. As a science educator, the dialogues between teachers and park rangers also made me reflect on invaluable opportunities to explore the significance of outdoor educational trips and acknowledge the importance of incorporating diverse disciplines, perspectives and voices in science and environmental education.

The second part of the conversation in the first and second focus groups was about the following general questions: What do you believe are the benefits, strengths, difficulties, and obstacles when designing learning activities outside the classroom? What are the teaching skills and institutional conditions required for learning outside the classroom? Those questions were relevant to discuss and for planning the visit to ‘El Morado’. In this process, and with the following quotations, I aim to analyse how pre-service teachers benefit from collaboration and dialogue with experienced science and environmental educators.

Clara, a practising teacher with more than 10 years of experience planning outdoor activities, was the first to share her insights about outdoor education. She began by discussing her motivations and advocacy for learning science outside the classroom:

> As science teachers, we must engage with the environment, studying ecosystems, care, and the current state of our planet. Yet, there is a palpable gap for students. We all know learning involves seeing, touching, and utilising our senses. Nowadays, we have significantly deprived students of this. Education has become heavily content-focused, emphasising skills and competencies. Experts are fond of assigning fancy labels to their concepts, but I have always championed that children learn by engaging and experiencing directly with nature.

In this excerpt, Clara reflects on the disparity between how science educators interact with the environment and how students experience learning. She highlights a noticeable gap in students' learning encounters, stressing the significance of direct engagement with nature. Clara critiques the current educational landscape, which she perceives as excessively focused on content and lacking sensory experiences. She argues that learning inherently involves using our senses and advocates a more experiential approach, where children learn by actively engaging with and experiencing nature first-hand. This excerpt underscores Clara's belief in the value of outdoor education as a means for direct sensory experiences and effective science education, challenging the prevailing emphasis on content-focused teaching methods. This insight makes me reflect on Freire's concept of conscientisation, which involves fostering critical awareness and questioning the systems that shape our experiences. In this context, conscientisation pushes in-service teacher to reflect on these systemic issues and advocate changes that prioritise direct, sensory engagement with the environment as a vital part of students' learning. Clara then explicitly addressed some obstacles and bureaucratic hurdles in the schools where she worked, discussing how outdoor activities have been progressively phased out due to procedural issues. One has to navigate myriad bureaucratic steps for approval to take students out:

> As teachers, we understand the need for protocols, knowing the children are our responsibility, but there should be some leeway [less stringent demands on teachers]. I greatly support outdoor activities, having organised many of them when possible, and I can attest that students benefit significantly from such experiences.

Clara's points set the stage for a discussion encompassing various viewpoints, centring around two primary themes: the tactile experience (direct contact with nature) and the bureaucratic steps for outdoor education. Ursula specifically commented on the challenges posed by university training, with its focus on the enormous amount of content in the science curriculum – at the teacher education level – and the need for more emphasis on understanding and interacting with the natural world when teaching sciences:

> At the university and across different educational levels, there is a tendency to concentrate on content delivery, with less emphasis on applying this knowledge to understand our environment and our interaction with it. This tension makes it challenging to transition education into a more action-oriented dimension. For example, visiting a park and experiencing it first-hand can foster a desire to protect it, vastly

> different from learning about it through a blackboard or a photograph, where it appears completely disconnected from our lives.

In this excerpt, Ursula echoed Clara's sentiment regarding the prevalent focus on content delivery in education, particularly at the university level and across various educational stages. She highlighted a notable lack of emphasis on applying this knowledge to comprehend our environment and interaction. Ursula identified this tension as a significant challenge in transitioning education towards a more action-oriented dimension – which can be connected with critical scientific and environmental literacies – suggesting an apparent disconnection between theoretical learning and practical application. She illustrated this point by talking about visiting a park, where first-hand experience fosters a deeper connection and desire to protect it, contrasting with the passive learning experience of studying it through traditional methods. Ursula's perspective aligns with Clara's advocacy of a more experiential approach to learning, emphasising the importance of direct engagement with the environment to cultivate a sense of responsibility and stewardship.

Discussing the role of first-hand experiences, Humberto added some insights to the conversation:

> For us, educating people and future generations about conserving and preserving natural resources is crucial. However, many need to be aware of the reasons behind conservation efforts. This task is particularly significant in places like the San Francisco glacier, a vital water source for Santiago. It is imperative to inform and educate visitors about the reasons for conservation in 'El Morado' and all wilderness areas across Chile.

Humberto added relevant information about the reasons for conducting outdoor activities. As I presented in Chapter 2, outdoor education provides students with authentic, contextualised opportunities to extend classroom-based learning, making the learning experience more relevant and engaging (James & Williams, 2017). Humberto's perspective prompted me to reflect on the true nature of conservation education. I believe that to embed conservation values effectively, education must go beyond simple information-sharing. Educating people about conservation and preservation should also promote critical awareness and inspire others to reflect on our relationship with the environment, as well as on the socio-political forces that shape and impact the exploitation of nature.

Following Humberto's intervention, Andrés advocated a more hands-on approach to learning, stating that mere reading about science or the environment is insufficient. Physical presence in natural settings is necessary for a comprehensive educational experience. He suggested that science education should involve regular field trips and interdisciplinary outdoor activities. Those activities should be incorporated into national teacher education standards and move beyond the traditional classroom setting. However, the approach of those activities should also be in line with the idea of promoting contextualised and critical approaches in science and environmental education.

5.2.5 Advancing interdisciplinary collaboration

The experience of park rangers working with schools and teachers from different disciplines in planning out-of-school activities was fundamental to starting a discussion about interdisciplinarity. Interdisciplinarity and collaboration in the production of knowledge show that this type of mutual support and learning networks can contribute to the construction of a more robust educational theory and practice and also function as a tool for professional development (McLaughlin & Black-Hawkins, 2007; Wang & Zhang, 2014). Collaboration and interdisciplinarity in outdoor education may foster the creation of new conceptual categories and methodological tools using concepts or procedures from other disciplines in an auxiliary relationship (Klein, 2017).

While interdisciplinary collaboration, as noted by Guerrero and Reiss (2020), can enrich pedagogical reflection through diverse experiences and perspectives, the role of park rangers in outdoor education often remains undervalued. This oversight has been spotlighted, emphasising the need for collaboration between teachers and park rangers to bolster environmental education initiatives (Slattery & Lugg, 2002). Collaborative efforts, including those involving park rangers, are vital for addressing human-wildlife interactions and promoting awareness of coexistence (Vayro et al., 2023). Park rangers are key actors not only because of their expertise in managing natural environments but also because they are crucial facilitators of interdisciplinary collaboration (Howard, 2013). Indeed, Humberto emphasised the potential of collaboration to 'transfer and share wisdom' and experiences. Moreover, he highlighted many connections and opportunities for inter and multidisciplinary collaborations:

> Many people visit here for religious, spiritual, educational, and sports-related reasons. There are plenty of perspectives here. Wilderness areas can be utilised in many ways. The primary thing is to see the benefit of nature and protect it. When nature benefits us, we should protect it for future generations.

> There are endless possibilities here in El Morado – opportunities in many areas, including physical education, biology, mathematics, geomorphology, etc. Also, I see opportunities to connect the visit with language [Spanish subject]; why? Because of the names of the plants. Wherever you look, everything is related to something here. Medicine, because there are medicinal plants. This is a natural laboratory.

By highlighting the benefits of nature and the importance of protecting it, Humberto emphasised the interdisciplinary nature of environmental conservation, which draws upon knowledge from various fields such as ecology, sociology, and many others. Moreover, Humberto identified specific disciplines that can intersect with exploring and utilising wilderness areas, including physical education, biology, mathematics, and geomorphology or geology. He also recognised the linguistic and medicinal dimensions of these spaces, illustrating how different disciplines can contribute to understanding conservation. Overall, Humberto’s statement underscored the rich opportunities for interdisciplinary collaboration and exploration within wilderness areas. Humberto also stressed the value of collaboration with teachers across different disciplines:

> Collaborating with teachers from different disciplines is highly significant for us, and I appreciate that we are [now] engaging in dialogue among other science and environmental educators. I have worked with many teachers over the last 20 years. Still, while we have not formally trained in pedagogy, our fieldwork experience allows us to explain concepts more effectively to people or children on-site.

This perspective is notable as Humberto does not consider himself a pedagogue, despite his over 20 years as a park ranger and being in charge of environmental education. Thus, he greatly values the contribution of teachers in the project, considering pedagogy as a discipline separate from environmental education.

From this perspective, interdisciplinary outdoor science activities can potentially organise scientific topics and ideas and answer questions across different disciplines (DeZure, 2017). Furthermore, outdoor activities provide an opportunity to develop problem-solving abilities, generally considered an instance of higher-order thinking within science courses. Thus, interdisciplinary outdoor science activities through collaboration generate common work objectives, addressing conceptual, procedural and attitudinal aspects across science subjects. Interdisciplinary teaching outside the classroom leads learners to have more meaningful learning experiences. Nevertheless, pre-service teachers might find it challenging to specify quality teaching itineraries for implementation in the school. Therefore, collaboration, and if possible a collaborative research process with other actors can be vital in facilitating interdisciplinary teaching.

5.2.6 Living in a bubble

Until this moment of the meeting, all the pre-service teachers had remained mostly silent. This situation may be due to respect and an awareness of the asymmetry in experience, particularly with Clara and the park rangers. Angelica was the first pre-service teachers to make a substantial contribution. Her intervention occurred approximately 20 minutes after the park rangers and in-service teachers had spoken. Angelica felt shocked about how teachers consider outdoor activities, and she said loudly that she had been living in a ‘bubble’, often disconnected from the natural world:

> I wanted to share my opinion on what Clara mentioned about how many teachers view educational outdoor activities as mere excursions or walks. I remember when I was in secondary school, we had the chance to go to the Río Clarillo Reserve, but it was just a day out, like an ordinary school break but outdoors. Now, I feel these kinds of opportunities are greatly wasted. Such experiences should be enhanced or utilised so students can reflect on their position and the ecological role of different organisms in an ecosystem. As science teachers, we should promote a certain attachment and understanding of what is really there. I just realised we live in a bubble – our homes, jobs, the city – but just because we are not in contact with these reserves or ecosystems does not mean they [ecosystems] are not there. We should take care of them.

Angelica critiqued some teachers’ superficial treatment of educational outdoor activities, when they regard them as merely excursions or walks. Recalling her secondary school visit to the Río Clarillo Reserve, she now laments the missed educational potential of such experiences. She highlighted the disconnection from natural environments caused by urban living and advocates a greater appreciation of these critical areas, emphasising the role of outdoor science in fostering this connection and awareness. The notion of alienation from nature and disconnection from the natural environment emerged again.

Then, Andrea resonated particularly with Clara’s and Andrés’ insights on our disconnection from nature:

> I want to continue with the ideas expressed by Clara and Andrés. Their insights resonated with me deeply, as I, as a student and a teacher in training, have observed that

> my colleagues [pre-service teachers] and I often prioritise academic achievements over tangible experiences. Yet, science encompasses all that surrounds us; it is the pursuit of understanding our world, the mechanics of its operations, and the interconnections within. One of science's most exquisite explanations is the equilibrium found in ecosystems. However, after listening to the conversation, I confess to a certain ignorance regarding the significance of elements within the ecosystem, such as the role of a solitary tree.

Andrea desires to build upon Clara's and Andrés' contributions, noting a personal revelation. She expressed a newfound understanding of the importance of outdoor science education and a desire to learn more. This perspective aligns with the view that environmental outdoor education requires a deep understanding and interaction with nature. Andrés highlighted this topic:

> As I have read in some documents, we often speak of humans and the environment as separate entities. However, it is crucial to teach children, youth, and adults that we are part of the environment, not apart from it. Many texts erroneously present 'humans and the environment' as if we exist beside it or it belongs to us. In truth, we are a component of the environment; what affects it also impacts us. This misconception needs correction through exploration and understanding.

Andres's comment made me reflect on the importance of unifying science and environmental education. It reinforced how often we perpetuate the false notion that humans are separate from nature or that we own it. Teaching children, youth, and adults that we are an integral part of the environment is crucial. However, correcting this misconception requires more than presenting facts; it calls for experiential learning and a shift in mindset to truly grasp our interconnectedness with the natural world and promote conscientisation. This has motivated me to reconsider how I approach these concepts in education, striving for a more unified, holistic perspective that blends science and environmental understanding.

5.2.7 Broadening pedagogical perspectives

These focus groups underscored the importance of diverse perspectives in addressing environmental education and the value of experiential learning outside the traditional classroom environment. They highlighted the need for a holistic approach that integrates the emotional, ontological, and intellectual dimensions of learning about and interacting with the natural world. According to Dávila and Maturana (2021), historically, humans ceased to perceive themselves as integral components of a unified whole, opting instead to sequester themselves as isolated entities. This divergence has engendered a pervasive sentiment, perpetuated across generations, that our actions exert no substantial influence on the global milieu – a notion ingrained in us through our upbringing, which negates our inherent interconnectedness. In contemporary times, even our most profound ignorance cannot veil the reality that we constitute an interconnected network; the events transpiring in one part of the globe invariably bear consequences on its antipode.

Linking this to collaboration, the focus groups' insights on environmental education reinforce the need for collaborative approaches that blend diverse perspectives and experiential learning. As Dávila and Maturana (2021) suggest, this multidimensional engagement challenges the outdated notion of separateness and fosters a collective responsibility towards the environment. Collaboration, therefore, is beneficial and essential in addressing the complex issues of sustainability facing our global ecosystem, illustrating how shared efforts can lead to a deeper understanding and more effective conservation practices.

5.2.8 Reflective practice triggered by diverse perspectives

At the end of each focus group and dialogical seminar, some reflective questions were asked of the participants. I called them 'exit tickets'. As an example, I presented the following questions, which were part of one the exit tickets, and Antonia's answers:

> *What are your impressions from today's meeting? Do you have any question, reflections or new ideas?*
>
> I found that the meeting was a very good opportunity and instance, where I could reflect more deeply on the role of field trips in the school context. One idea that stuck with me was that a field trip doesn't have to be to a distant location from the school; it can be within the local area. I believe this can be beneficial as it allows for reflection on the context in which the school community is situated. Additionally, I was left thinking about the best timing within the unit to conduct these trips. Should they be before or after introducing the content? Will it impact learning in the same way?
>
> *What other types of instances would favour the discussion? How can today's session be improved?*
>
> Perhaps, by introducing us to the way of planning a field trip or a didactic unit that includes it. It could also be beneficial to listen to experiences from high school or primary school students who have had field trip experiences. Regarding the second

question, I would have liked to know more about the school context in the United Kingdom to see to what extent it can be compared with the situation in Chile.

Exit tickets were helpful to my own reflection as a researcher, and they also helped me formulate questions for the subsequent interviews after visiting the park. The use of 'exit tickets' at the end of each session was instrumental in fostering a reflective dialogue. These brief feedback forms helped not only in reflecting on the day's discussion but also in shaping the questions for subsequent meetings. This reflective tool proved invaluable for my analysis as a researcher and for encouraging ongoing inquiry among participants.

5.3 Influence of collaboration and CPR on pre-service teachers' outdoor education expertise

In this third and final section of the chapter, I aim to address the impressions of the pre-service teachers after having carried out the collaborative planning and visit to 'El Morado'. Subsequently, I discuss how the prior collaboration effectively enhanced the expertise of the pre-service teachers.

5.3.1 Visiting the park and 'a biggest adventure' for pre-service teachers

Nine of the original group members participated in the park visit. One of the in-service teachers was pregnant and could not, therefore, participate in the activity. Similarly, one of the science educators (an ecologist) could also not join the visit that day due to personal reasons. Therefore, the group consisted of Ursula, Clara, Angelica, Andrea, Antonia, Paulina, Humberto, Andrés, and myself.

Notably, during the second focus group, the primary challenges and necessary preparations for visiting the park were extensively discussed as part of the collaborative research process. Humberto and Andrés played a pivotal role in providing pertinent information. The critical recommendations deliberated upon during the second focus group included having a substantial breakfast; donning appropriate attire suitable for the prevailing season to shield oneself from the sun and sudden temperature changes – ideally opting for long-sleeved tops and trousers; wearing sturdy, closed trekking shoes designed for traversing high mountain terrain, ensuring ankle support and a robust sole grip; safeguarding against sun exposure with UV-protected sunglasses, a suitable hat, and sunscreen to protect the skin; bringing along sustenance such as cereal bars, nuts, fresh fruits, and energy bars, along with an ample supply of water. Humberto advised consuming water in small, regular portions to prevent dehydration or fatigue during half-day hikes, recommending a litre of water per person. Humberto also highlighted the imperative to assess our physical capabilities, training, knowledge, and experience before embarking on the hiking activity, emphasising that people should exercise caution if underlying health issues exist. Andrés underscored that the ascent trail to the San Francisco glacier presents a moderate to high level of complexity, with the entire route typically taking around three and a half hours to complete, contingent upon the visitor's physical fitness level.

Subsequently, the visit was organised via email, and the final logistical details were agreed upon via WhatsApp. Direct communication with participants was essential to manage the logistics operation. For instance, how can we coordinate arrival times in two vehicles to travel to the park? Besides, as in a regular school outdoor activity, all pre-service teachers monitored the weather conditions, road status, and sanitary restrictions from the Chilean Ministry of Health. The journey from Santiago to the park takes approximately 90 minutes. Initially, in the final interviews, when I asked about this collaborative process and the trip to the park, Andrea stated:

> It was all a great adventure [Laughs] – the travel, the fact of climbing, meeting in San José de Maipo, getting there, talking with Andrés and Humberto, then climbing up until the glacier, I think that was the biggest adventure. It was a considerable challenge. However, I think the journey was what I enjoyed the most. I had never taken the time for proper trekking, to start looking at my surroundings, and realise everything, all the organisms living there, to think about perhaps what geological events had occurred, how these organisms are related, whether this is native or not, I had never taken that time. However, I started there and enjoyed it, but I also got exhausted [Laughs]. I was drained.

Then, when Andrea remembered all the 'adventure', she also made a point regarding all the previous activities needed to plan the visit to the park, and she imagined herself as a teacher:

> On the way to the place, I also reflected. Could I design a pedagogical activity like this on my own? Because it is complex. If it was difficult for us, how would I do it with a bunch of kids? I saw myself, tired, climbing up, in a mess, and with kids, oh, it would be even more complex.

When asked specifically about her self-confidence and whether she believes she could develop a pedagogical outdoor activity by herself, Andrea responds:

> By myself, it would be complex. However, based on a collaborative effort, like, I do not know, a science department or even with another science teacher. In that case, I would be capable, not just because of my abilities or time, but maybe I would like to see some difference of opinion with a colleague. I really would not want it to be magnificent. I prefer to avoid going out for it to carry out just a walk. I would not want that because the opportunities the park truly offers are immense, so I would want to use an opportunity like that and not have the kids think it was just a walk.

In this passage, Andrea reflected on the complexity of organising an educational field trip alone, emphasising the collaborative nature of such endeavours. She acknowledged that while she might find it challenging to orchestrate the field trip independently, she would feel more capable and confident with the support of colleagues, particularly within a science department or alongside another science teacher. Andrea valued the diversity of perspectives that collaboration brings, suggesting that differing opinions among colleagues could enrich the experience for herself and the students. She wanted the field trip to be meaningful and impactful rather than merely a casual excursion. Andrea is concerned that if the field trip were perceived as just a walk, it would not fully leverage the park's immense opportunities for learning and exploration. This passage highlights Andrea's commitment to providing enriching educational experiences for her students and her preference for collaborative, purposeful planning to achieve that goal.

Regarding the elements or considerations when planning a pedagogical field trip, Andrea mentioned various points discussed in the focus groups, particularly in the second one. However, she also mentioned elements discussed in the dialogical seminars:

> The most important thing would be transportation management, perhaps the logistics. This is the most considerable complexity in planning. However, regarding pedagogy, the most important thing is to work with an instrument because it is such a vast place with constant stimuli. The kids would definitely need a guideline with which they could reorient themselves or reorganise themselves in groups because I believe that even with three teachers, it would be very complex for the group size classes we have here in Chile, which is enormous. Keeping them focused and preparing them before field trips would be very complex, but not necessarily giving them a spoiler of what will happen. Still, yes, what we will work on because I like it a lot (…). I remember Michael's workshop and the surprise factor; I liked that too much. I refrained from looking at

> pictures from there, from 'El Morado,' and surprised myself; I just let myself be surprised.

In Andrea's analysis of planning a field trip, she highlighted the critical aspects of effective transportation management and logistics. She acknowledged the complexity of these tasks, particularly in managing the vastness of the location and the constant stimuli encountered during the trip. Andrea emphasised the necessity of providing students with clear guidelines to help them navigate and organise themselves, especially in the context of large class sizes typical in Chilean schools. She valued the element of surprise in educational experiences, recalling a seminar she attended that emphasised the importance of the 'surprise factor'. Andrea believes in allowing students to discover and be surprised by their surroundings rather than overwhelming them with too much information beforehand. Overall, Andrea's expertise lies in recognising the logistical challenges of field trip planning while prioritising student engagement and the element of surprise to enrich their learning experiences.

When I asked Antonia about logistical elements, specifically what things she thought it would be necessary to anticipate or manage, she replied:

> The first thing would be safeguarding and safety measures. I do not know if there, like in that CONAF office, they have like a place to attend to, perhaps, more than one child because, it could be 10, even, like that capacity to be able to attend to them and provide them with first aid, at least, and the facility to be able to bring them down quickly, if it is something urgent because I imagine that perhaps, a child might have a drop in sugar, if they have insulin resistance, which nowadays, is quite common and, needs to, urgently, come down, I think that is important to consider and, also, I was thinking about something, I remember that (…) I do not know who it was (…) Andrés or Humberto, mentioned that certain people, with certain conditions, could not climb to do that trek. I thought, what happens with the students who have those conditions? Where do we leave them? Do we take them and leave them sitting outside? [Laughs] And wait for the rest to come down?

Reflecting on Antonia's analysis of safety considerations for the field trip, I am struck by her deep commitment to student well-being. Her expertise is evident in how she prioritises safety protocols and advocates inclusive practices to ensure every student feels cared for and included. Antonia's emphasis on having appropriate facilities, such as a well-equipped CONAF office capable of accommodating multiple children and providing first aid, demonstrates her thorough approach. I am particularly moved by her awareness of the need for swift action during emergencies, especially for children with health issues. Her concern extends to students who might be unable to participate in certain activities, and she thoughtfully questions how they would be accommodated during the trip. This reflection makes me consider how I, too, can adopt a more comprehensive and inclusive perspective when planning educational outdoor experiences.

Another common topic emerged among all pre-service teachers interviewed. All of them considered a previous visit to the park to be essential. For instance, Antonia mentioned:

> First, before planning something or presenting it to the school, the first thing to do as teachers is to go to the park because as much as one reads and looks for photos, it is different.

Regarding the pedagogical skills needed to organise, plan and carry out an outdoor activity, Antonia, Paulina, Angelica and Andrea highlighted the relevance of collaboration and opportunities for interdisciplinarity. This theme was a common topic among all pre-service teachers:

> I think teachers will need the ability, perhaps, to develop interdisciplinary activities and plans, like really working in a team; it is not like, I do this part, you do the next, and let us try to make them fit together, or I am dealing with this learning objective and which one are you dealing with? We can join them in an interdisciplinary way but as a plan from the beginning of the year. (Paulina)

> As a science teacher, I would also connect it with history because there have been different historical events at El Morado, maybe because of the mines and the fossils people found there. (Antonia)

> I would also connect it with other subjects and carry out this pedagogical outdoor activity, not only for biology or ecosystems but also for some history topics. (Angelica)

> [Also in arts] I would formulate a plan so the children can generate a resource after the pedagogical outdoor activity – for instance, an essay, a video, a poster, or something similar. (Antonia)

In this discussion, pre-service teachers showcase their expertise in outdoor education by highlighting the importance of interdisciplinary collaboration and integrating various subjects into outdoor activities. Paulina emphasised the need for teachers to collaborate to develop interdisciplinary plans from the start of the academic year, advocating for a comprehensive educational approach. Antonia builds on this notion by suggesting connections between science and history, acknowledging the historical significance of the outdoor location and advocating cross-curricular exploration. Angelica further supported the interdisciplinary approach by proposing connections with additional subjects beyond science, such as history, to enhance students' learning experiences. Additionally, Antonia suggested incorporating arts into outdoor education, underscoring the value of creative expression and providing opportunities for students to produce resources like essays, videos, or posters. The participants demonstrated their expertise by recognising the diverse educational opportunities from visiting 'El Morado' and anticipating interdisciplinary plans to maximise student engagement and learning outcomes. Regarding technical equipment, common elements must be considered before visiting the park. There are also common points that the pre-service teachers are now aware of:

> We were in winter, and it was freezing. However, just that day, the sun came out, and the girls and I were all bundled up, and we died of heat, but the sun hid, and I even caught a cold; it was like a few minutes that happened, and I caught a cold, so, the clothes you wear, how you equip yourself, I think it has to be something super rigorous, to be able to prevent the kids from getting sick, from having, I do not know, complications higher up, or on the way maybe, someone gets sunstroke, it is necessary I think, those, like not jockeys, but those special hats [Makes a gesture of what the hats would be like] like they cover the neck too. (Andrea)

Paulina also highlighted the importance of bringing proper clothes to the visit.

> Yes, and a first layer, like a T-shirt, helps you anticipate both the cold and the heat and keeps you from getting sick when it cools down.

When asking the pre-service teachers how to approach this issue of equipment and footwear at the school level, they mention certain complexities and concerns:

> It is super complex because often, schools are super stingy, a bit with money, like, already, the fact of a bus to take them there, the entrance and all, the food, it would already be a considerable expense that I think that like they would not allow another expense. Still, I wonder if CONAF can provide some funding, like a department in education, which can help those students. This support would be pretty valuable. (Paulina)

The interviews explored previous considerations before the visit regarding communication and essential knowledge about the proper visit to the park:

> The preparation was chaotic because, as I told you, I needed the sneakers or the requirements for clothing to go to places over there. So, I talked with the other pre-service teachers about whether they had them to lend me, and it went wrong. Ultimately, I had to go the same Monday to buy. (Angelica)

During the second interviews, I asked them whether they could manage to organise, plan and carry out an outdoor activity. After the project, Angelica mentioned relevant insights about collaboration:

> I would look for support; for example, I would not go alone with the kids. I would invite more teachers or parents because they require, like, I do not know if supervision, but it is more than anything, like for support, so to speak.

For Paulina, the experience was valuable because this experience made her feel and reflect as a student:

> Having had this experience put me in the place of the students. I was thinking about what I would need as a student. What am I going to do to get there? So, that also generated an emotion of what they would live in the future when I carried out a pedagogical outdoor activity and had solutions, like not the transport we see over here.

Andrea also highlighted all the relevant administrative information the teacher may need for the outdoor activity. Communication with park rangers will be essential in this regard:

> As a teacher, I must contact the park rangers from CONAF to manage all the administrative tasks. They [park rangers] have, like, complete knowledge of the places where they are, because even with the visit I made, I could not say that I am an expert in the Cajón del Maipo because there are details and data that, sometimes, one does not retain in one's mind long term.

Angelica similarly highlighted the relevance of having a previous meeting with park rangers:

> I think contacting them and having like a prior talk before going up to the outing is essential for the kids to contextualise themselves with the place and in a way like, change the switch, that capital city switch, from where the school comes out and all the topic, to be able to already, fully enter what a place where although there is a specific type of organisation, it is more than anything, connecting with nature.

Reflecting on the insights from pre-service teachers, I see how their expertise in outdoor education is showcased through their thoughtful approach to organising and managing these activities. Angelica's emphasis on seeking support and collaboration stands out, as she recognises the importance of having additional supervision and assistance for a safe and successful experience. Paulina's reflection on placing herself in the students' shoes and understanding their needs shows an empathetic approach that allows her to foresee potential challenges and develop practical solutions, such as arranging transportation. Andrea's focus on the administrative side of outdoor activities highlights the value of effective communication with park rangers for logistical support and obtaining essential information about the site. Her recognition of the expertise and resources offered by park rangers reinforces the collaborative essence of outdoor education. These reflections prompt me to appreciate how these pre-service teachers demonstrate their capability by addressing practical, logistical, and empathetic considerations, ensuring that outdoor learning is both safe and enriching for students. Overall, the participants demonstrated their expertise by considering various practical and logistical aspects necessary for organising and executing successful outdoor educational experiences while emphasising the importance of collaboration with park rangers and empathy in ensuring the well-being and learning of students.

5.3.2 Difficulties and challenges: Relevance of research support

> The tricky thing is daring to do it. It is challenging to manage it. I mean, I do think it is not easy to manage it. However, I think it is more challenging to dare and propose the idea because, currently, in the school, there is still this prejudice of avoiding going out because they become recreational walks instead of pedagogical field trips, or they give it or they simply, do not trust in the autonomy of the students and teachers. (Andrea)

In this statement, Andrea demonstrated her expertise in advocating for outdoor education despite existing barriers and misconceptions within the school system. She highlighted the importance of daring to propose the idea of outdoor activities, emphasising that while managing such activities may present challenges, the real difficulty lies in overcoming institutional prejudices and preconceptions.

Regarding a hypothetical question about convincing and tackling prejudice about outdoor activities, Angelica mentioned something very inspiring related to the value of research:

> First, I would tell him to allow me to try it and show him the evidence about learning in outdoor scenarios. I can show them the studies and papers that have been done, although they may not read them. It is like, I know what I say. It is not only me. Science and research also support the relevance of outdoor education.

Regarding the benefits for students learning, pre-service teachers highlighted some categories that we did not discuss in the focus groups but that Michael's workshop highlighted during the seminar:

> The benefit would be, more than anything, to test their autonomy and promote autonomy because even in the classrooms, like the role of education, they are still not protagonists of their education. (Antonia)

> Another benefit is that they will be able to get to know part of the nature that exists in Santiago, well, in Santiago, I could not say in the country, because that would be too much, but to get closer a little to the surroundings that exist and perhaps, from there gradually get more into the species that we can find here. (Andrea)

Other skills Antonia, Angelica, Andrea, and Paulina highlighted were empathy, autonomy, leadership, management, confidence, and research skills. Regarding research skills, Angelica particularly appreciated the opportunity to learn more about interviews:

> I had never considered the interviews at the time of conducting the research. I also needed to learn what semi-structured interviews are. Now, I also consider them when contacting people before organising a field trip.

In this excerpt, Angelica enhanced her expertise in advocating outdoor education by highlighting the importance of using evidence and collaborative research to address prejudice and convince others of its value. She emphasises the significance of showcasing studies and papers that support the benefits of learning in outdoor environments, recognising that scientific evidence can serve as a compelling argument to counter scepticism. Angelica's approach reflects a deep understanding of the need to ground educational practices in empirical research and leverage evidence-based arguments to advocate innovative pedagogical approaches.

Furthermore, the pre-service teachers exhibited expertise by identifying various benefits of outdoor education beyond academic learning. Antonia underscored the opportunity for students to develop autonomy, challenging traditional classroom dynamics where students are often passive recipients of education. Andrea emphasised the value of connecting students with nature and fostering an understanding of their surroundings, highlighting the potential for outdoor education to promote environmental awareness and exploration.

Moreover, the mention of research skills by Angelica, Antonia, Andrea, and Paulina showcased their awareness of CPR and the broader educational implications of outdoor activities from a vivid experience and the expertise of experienced teachers and park rangers. They recognised the importance of research skills in conducting academic inquiries and organising practical experiences like field trips. Angelica's reflection on the role of interviews in her learning process exemplifies the transferability of research skills from academic contexts to real-world applications, illustrating the depth of expertise cultivated through engagement with outdoor education initiatives. These previous thoughts and reflections showcase an enhanced expertise in comprehending the multifaceted benefits and challenges of outdoor education, highlighting pre-service teachers' adeptness in advocating for its integration into educational practice.

Chapter 6. Critical scientific and environmental conscientisation

Rebirth

I am the Maipo River, arriving like a thread of life to this place, dismembered, profaned, and disfigured.

I traverse villages and cities, where I suffer, wounded and despoiled; death, sorrow, pain, and contempt remain as sores in my veins.

At the end of my journey, I feel the intensity,

I feel the beginning of the encounter.

I yearn to embrace the sea, to become part of its infinity.

What fear I feel!

My hope is revived with the tides.

Together we are life, sweetness, and salt,

Maintaining our connection, intertwined forever in the currents.

Now that everything seems to be horizons, beaches, and dancing life,

Let us be the same waves,

Let us be the same feather that spreads its wings,

A single current.

I come from far away,

Where one can see and touch the sky.

I return, sooner or later.

I am ephemeral, transcendent.

Wake up.

I am Glacier,

I am your reborn body of water.

Wake up.

El Renacer, a Poem by Andrés Ríos and Camila Silva, adapted and translated by myself.

Preface

The previous poem and this preface are included as a way to start the last chapter of this thesis and to start reflecting on the current climate catastrophe. The poem is a provocation to be carried away by one's senses, an inducement to return to the importance of perceiving the actual experience in connection with a critical reflection of the circuit and metabolism of living systems, including human, non-human or – as for some indigenous communities cosmovisions – more-than-human entities. This thesis provides an open space to imagine the future and reflect on the past on an intertwined nonlinear timescale. I hope throughout this thesis readers can question what lies beneath the visible world by imagining a view of the complexity of nature, seeking out less perceivable and material worlds, based on the organisation of relationships within them.

Readers can immerse themselves through the following introduction to the fieldwork. Hopefully, they can connect, feel, perceive, hear, look, imagine, dream, learn, discover, and finally reflect on hope in the global ecological crisis. Through this text, readers might be able to understand what I lived through with a group of participants in one of the great natural features of the globe: The Andes mountains in the south of America.

*

Imagine a group of people in South America – mainly students and science educators – visiting a national park in the year 2030. The area is surrounded by the majestic Andes Mountains which is recognised as a national *Natural Monument*. Natural monuments in Chile are non-human (or more-than-human) natural features of outstanding or unique value because of their inherent rarity, representative of aesthetic qualities or enlightening cultural significance. This specific natural environment aims to protect native flora and fauna, relevant geological sites, and biological processes. The Monument is protected by the rights of nature, established in the new constitutional law approved in 2025, to conserve a glacial cirque located at an altitude of 5,060 meters in the heart of the Andes, covering more than 3,000 hectares. The endemic flora and fauna in the park include at least 300 native species of plants, and over 126 native species of animals. The composition of the fauna is distributed as follows: Mammals: 31 species (25%); Birds: 81 species (64%); Amphibians: five species (4%); Reptiles: nine species (7%). Of the fauna, nine are exotic species and the rest are native, some of which were in danger of extinction before the adoption of the Conservation of Habitats and Species regulations.

In this imagined field trip, students and teachers investigate nature, specifically hydrologic systems, and water's importance. The collaborative research process takes place in the beautiful cordilleran scenery where the sound of birds accompanies the research process. Moving along the trekking path, the group and park rangers reflect on the impact of the climate crisis on the place. Some colours in the landscape have changed due to global warming and prolonged periods of drought. There is a broad and rocky path, and along the way, the *Panimávidas*, small pools of mineral waters produced by the passage of snow waters, are surrounded by wildflowers and native birds. The solemnity of the landscape unexpectedly stops the discussion because a massive glacier called San Francisco is welcoming stupefied students. A mighty dirty glacier stands for them to admire.

In this stunning place, the group can hear the sound of the Morado's river flowing in the absolute tranquillity that the landscape conveys. But also, there is an incredible opportunity: students can contemplate, perceive and be aware for the first time that a river is born from a glacier. After some discussion with science teachers and park rangers, they realise that the river is their city's primary water supply source. One of the park rangers introduces to the discussion the importance of water for indigenous Mapuches' communities in Chile. Water from the glacier is the Mollfün or sap of the Ñuke Mapu (Mother Earth) and all living beings that are part of it exist through water. For the Mapuches, the environment is determined by the conviction that everything is related to everything through a complex and interconnected network of relationships between bodies of water, human bodies, flora, fauna, non-human entities, territories, and more-than-human entities, such as glaciers.

The San Francisco Glacier is one of the most important drinking water sources for the capital city where all of them live. Like other glaciers, it is fed by the snowfalls concentrated in winter. Sadly, due to long-term warming of the Earth's surface, snowfalls are becoming increasingly scarce, and this glacier is melting due to the increase in temperature. If that were not enough, in the same place and literally underneath the natural Monument a monster slept, an invasive mega hydropower project threatened the water supply for over eight million people. However, due to community action and citizen demands, this project was stopped in 2024. The project likely would have devastated the natural Monument and the hydrological system of the capital of Chile, risking more than half of the country's water access.

As the students work and discuss, teachers remember an outdoor pedagogical activity from their pre-service teacher preparation. They seem, once again, to grasp the interconnection and interdependence between different ecosystems, nature, and human activity. The teachers remember how to plan and develop an outdoor science activity from the approaches of critical scientific and environmental literacies. Previous teachers' preparation and dialogue with park rangers were pivotal to understanding complex socio-environmental issues and how individual decisions and actions affect the environment at local and global levels.

Collaborative professional development experiences in outdoor settings were crucial to linking a field trip with a new environmental education curriculum that focuses on increasing environmental conscientisation and understanding that environmental and ecological education in the global climate catastrophe is a collective endeavour. After this field trip, teachers and students developed projects to share with the community, recognising that socio-environmental issues transcend disciplinary boundaries and demand collaboration, action, and dialogue with others.

*

This chapter aims to answer the third and final question of my PhD thesis: To what extent can critical scientific and environmental literacy approaches be promoted through outdoor education? In addressing this, Chapter 6 examines opportunities emerging from empirical data to apply and contextualise critical approaches during visits to the 'El Morado' National Park in San José de Maipo, Santiago, Chile. It is important to note that this area is still affected by the environmental conflict known as Alto Maipo, as reported by the Chilean Institute of Human Rights in 2024. Therefore, this chapter will gather insights to discuss opportunities to promote critical literacies – grounded in the concept of conscientisation, as described in Chapter 2 and 4 – and to understand the potential of environmental conflicts as scenarios for analysing power dynamics and networks of actors, including human, non-human, and more-than-human entities involved in socio-environmental.

The first part of the chapter, titled 'The potential of the geographical area of 'El Morado' for promoting critical science and environmental literacies' analyses opportunities arising from the hydrological system in Santiago, Chile, and explicitly connects these to the conceptual and theoretical frameworks presented in Chapters 2, 3, and 4. This section also explores how critical literacies relate to climate, socio- and eco-justice, and contextualises the concept of sustainability within Chile's neoliberal agenda. Additionally, I reflect on my own process of conscientisation. The main topics I discuss here are in tune with analysing interdisciplinary and collective opportunities to promote scientific and environmental literacies which emerge from outdoor education based on the relevance of the geographical location of 'El Morado' and the key role of the Maipo River.

The second part, 'A monster in the park', describes and examines the network of actors involved in the Alto Maipo project and analyses in detail the socio-environmental conflict in the Chilean Andes due to the impact of this project. Topics discussed include neo-extractivism, the neoliberalisation of nature, human-nature interdependence, and the rights of nature, among others. As discussed in Chapter 4, from 2020 to 2022, I conducted interviews, conversations, focus groups, dialogical seminars, and a final visit to the national park with pre- and in-service teachers, scientists, and park rangers. This section also includes insights from a 2023 interview with the former coordinator of No Alto Maipo, an environmental activist leader of a movement that emerged in 2007 against the development of the Alto Maipo project.

In 2024, I also invited a Chilean photographer and activist, known as Blacklights, who has documented environmental conflicts in the Andes Mountains, and he agreed to collaborate with the group and share some photographs now included in this chapter. The aim was to gain valuable insights to expand collaboration and enhance the understanding of collective and critical scientific and environmental literacies.

Finally, the third part ‘A glacier as a more-than-human entity to develop conscientisation’ explores discourses of critical awareness, interconnection, and hope, considering the San Francisco Glacier as a transdisciplinary actor to promote critical literacies and conscientisation processes. Furthermore, I discuss how socio-political discourses around water management, particularly regarding the conflict with Alto Maipo, can be made more pedagogical (Giroux, 2004).

As noted in Chapter 4, ‘El Morado’ natural monument attracts roughly 15,000 visitors per year, including students and science teachers from various schools, mainly from Santiago, as well as tourists and the general public. The role of park rangers in this national park is crucial, due to their proximity to significant events, their local knowledge, and their special relationship with the natural monument and the glacier. Therefore, a focus of this last section is to gather voices and discourses from and about park rangers as key actors to support critical approaches from outdoor education, working as non-formal science and environmental educators (see Torres-Olave & Guerrero, 2024).

6.1 The potential of the geographical area of ‘El Morado’ for promoting critical science and environmental literacies

6.1.1 Geographical context of ‘El Morado’ and the relevance of the Maipo River

To establish context and contemplate more fully the potential of visiting the park for supporting scientific and environmental education, I initiated my inquiry by thoroughly researching relevant details about ‘El Morado’ and its relationship with water and hydrological networks in the region. Inspired by a poem written by Andrés Ríos and Camila Silva and the photographs provided by Blacklights, I call this process ‘analysing the veins of Santiago’ (see Figure 15). Viewing the journey depicted in this chapter as the movement of a body of water, I envision its veins as a series of tributaries and flows – some academic, some experiential, some constructed collaboratively with project participants, some expressed through art, and some seeping into the soil, awaiting activation in the future (Neimanis, 2012). As I described in Chapter 4, this initial phase involved analysing official policy documents from the Ministry of the Environment, the Ministry of Agriculture, and the Chilean system of protected areas, as well as studying the Management Plan of the natural park ‘El Morado’ (Management Plan, 2011). The latter document is an official guide for park rangers, and it constitutes a key document to analyse opportunities to enrich the experiences of visitors. Therefore, my objective in undertaking this preliminary investigation was to disentangle the connections between ‘El Morado’ and the diverse ecosystems spanning a 250 km^2 expanse in the central zone of Chile. Through this process, I identify potential opportunities to raise awareness by visiting the park and also ways to reflect on my own process of conscientisation.

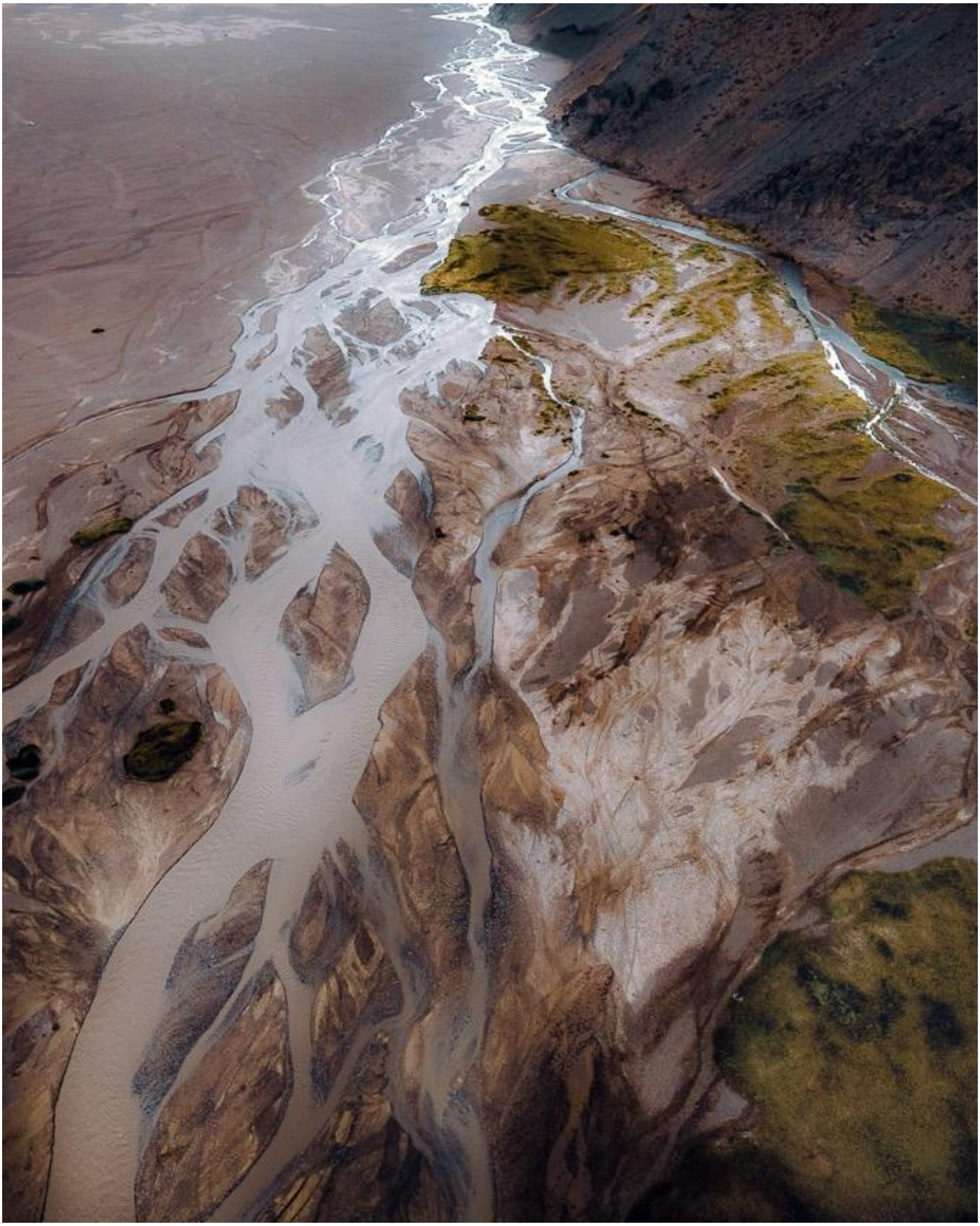
Figure 15. Veins of Maipo River. (Source: Blacklights)

In the first interviews with park rangers and during the visit with group, they started talking about the potential of the park ‘El Morado’ as a great opportunity for outdoor learning in terms of awareness of interconnected systems. They – with great enthusiasm – narrated stories accumulated over the last 25 years about the diversity of the flora and fauna of ‘El Morado’ and the important meaning of a natural monument in Chile. Furthermore, they highlighted the connection between the Andes Mountains, the rivers and the glaciers, which, according to the park rangers, are generally unknown to the residents of Chile’s capital city, as well as the entire hydrologic system in Santiago.

> The Monument [‘El Morado’] is a natural resource which offers multiple opportunities. It has a geological resource, a fauna resource, very beautiful. Everything here is related to the Andes Mountains. It has a floral appeal. The Monument has an area of 2,900 hectares. Within that surface area, it is a very important water resource. For instance, the San Francisco Glacier is the most impressive for the visitor or for the people who come to visit this wild area. When schools come, this is the most impressive. Because through the glacier we can know the origin of the water that nourishes the commune of Santiago. So, we can study the water cycle. From there, we can relate it to vegetation, and ecosystems, starting from a glacier. (Andrés)

Andrés’ portrayal of the El Morado nature reserve demonstrates how outdoor education can facilitate conscientisation and potentially promote critical scientific and environmental literacies. Emphasising the area’s diverse geological formations, rich wildlife, and unique plant life – all intimately connected with the Andes mountain range – he highlights the interconnectedness of natural systems. This approach encourages visitors from schools to develop a critical awareness of their environment and its impact on human communities, such as recognising how the prominent glacier supplies water to Santiago. In my view, this understanding fosters a sense of conscientisation and responsibility and prompts reflection on our relationship with nature.

Engaging learners in hands-on exploration of the glacier and connecting it to the water cycle, vegetation, and ecosystems, Andrés moves beyond passive observation. This experiential learning enhances critical awareness enabling visitors to analyse environmental components and comprehend the effects of human activities on these systems. Consequently, outdoor education at El Morado has the potential to contribute to make informed decisions from a deep connection with the ecosystem at the park and take meaningful action towards conservation, integrating knowledge with critical reflection and practical application.

Covering 2,900 hectares, the Monument plays a vital role as a water resource, with the presence of the San Francisco Glacier being particularly remarkable (see Figures 16 and 17 for an idea of the landscape at the end of the visit at ‘El Morado’). According to Humberto:

> This glacier not only captivates visitors but also serves as a critical water source for the capital of Chile. Additionally, the Monument offers valuable educational opportunities, particularly for school field trips, with the glacier serving as a tangible illustration for studying the water cycle and its intricate relationship with vegetation and ecosystems.

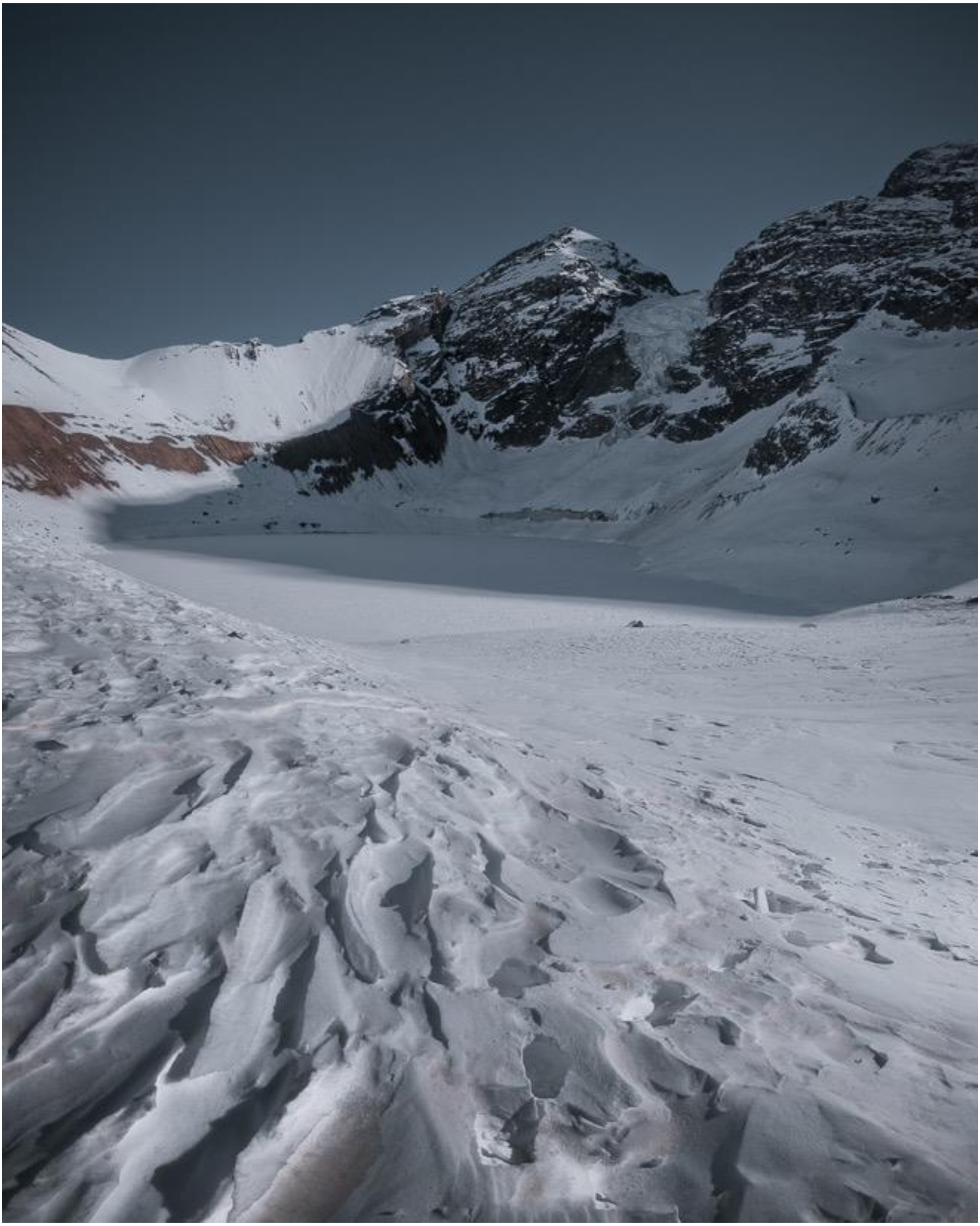

Figure 16. San Francisco Glacier at the end of the trekking path at ‘El Morado’ natural monument. (Source: Blacklights)

Figure 17. San Francisco Glacier in summer. View at the end of trekking while visiting 'El Morado' natural monument. (Source: Blacklights)

During the interviews, Andrés and Humberto frequently mentioned the Management Plan of 'El Morado' natural monument as their main 'pedagogical' resource. Therefore, analysing this document was relevant for analysing opportunities to teach and learn about ecosystems in the park and also to anticipate the visions and approaches of environmental and potential scientific literacies. Humberto highlighted the relevance of this document in his role as an environmental educator by saying:

> The Management Plan is a document where you can find everything related to the 'El Morado': its species, animals, and birds. Indeed, all the information about the geology of the place is in that document. You have to read it, without fail, it is a bible. The Management Plan is a bible for us as park rangers. And you have to read it, without fail, to find out how to educate people about the environment. Additionally, I read

> books by Adriana Hoffman, about reptiles, and birds. So, in this way, I started cultivating myself.

The metaphor of the management plan as a “bible” highlights the intertextuality of the discourse, emphasising the document’s perceived authority and indispensability. This metaphor positions the plan as a fundamental text, suggesting that its contents should be followed and respected, much like a sacred scripture. Through the lens of critical discourse analysis, this framing is significant as it reveals how language and metaphors contribute to constructing the power and importance of the document. A critical examination of the management plan makes it clear that the document provides a thorough and detailed account of all aspects related to the park, establishing itself as a key source of information. Overall, the Management Plan provides a structured approach to managing and conserving the geographical area, ensuring activities align with ecological, social, and legal frameworks to achieve sustainability and conservation goals. For instance, the document outlines a comprehensive management and planning framework focused on the geographic and administrative specifics, and the legislative context of ‘El Morado’. The Plan starts by detailing the ‘contextual framework and definition of objectives’, covering the general geographical and administrative location; legal, political, and administrative framework relevant to the property; and specific objectives for land use and management. Subsequent sections describe a ‘characterisation and diagnosis’ of ‘El Morado’, providing an in-depth analysis of the land’s physical characteristics, such as topography, climate, geomorphology, geology, soils, hydrological systems, flora, and fauna, as well as socio-economic factors like main productive activities and social, cultural, and organisational aspects in the zone around the park. This section also addresses the territorial diagnosis, emphasising the environmental value, state of conservation of native flora and fauna, vegetation and soil conditions, and soil erosion.

The document then transitions into ‘zoning and analysis of alternatives’ focusing on the management orientation for various territorial management units, followed by a ‘territorial Management Plan’. This section includes spatial planning for management activities aimed at direct use, restoration, conservation, and protection across different units. This plan also specifies cross-cutting management programmes covering administration, external relations, and main management activities such as biodiversity protection, natural condition restoration, and sustainable use.

The self-cultivation process is portrayed by Humberto as an essential part of being a park ranger. This point is relevant at the moment of thinking of park rangers as ‘non-formal’ science and environmental educators. As Humberto mentioned in the first focus group (see Chapter 5), he does not consider himself a pedagogue or a teacher. On the contrary, he identifies himself as ‘merely’ a park ranger who is in charge of environmental education. This perception, therefore, can suggest a viewpoint where individual responsibility towards self-improvement and education plays a critical role in the broader context of environmental and scientific literacies. Also, what the relevant plan can offer in terms of visions and perspectives for science education is relevant. There are some opportunities from this document to discuss broader issues and to understand what the discourses are that can perhaps explain why there is an environmental conflict in the area. For instance, according to the Management Plan (2011), the area was initially designated as a ‘Tourism National Park’ by the Ministry of Agriculture in 1974. However, it was reclassified by the Ministry of National Assets in 1995 to its current status as a ‘natural monument’. The primary aim of this particular natural monument is “to provide greater protection to the entire Morales River Basin as one of the scarce examples of the glacial process originating in that central Andean sector”[2] (Management Plan, 2011, p. 3). This aspect concerning the protection and glacial processes will be further discussed when analysing the impact of Alto Maipo in the area and particularly on the San Francisco Glacier. Nonetheless, it is valuable to consider how emerging discourses from environmental regulations that legally define a natural monument, such as the role and significance of dedicated areas, can help in protecting and conserving valuable ecosystems.

When the park rangers discussed the educational opportunities, they demonstrated a thorough understanding of the significant learning value offered by the rivers in the area. All this information was described by them almost as is word-by-word written in the Management Plan. Park rangers described the geographical context of the park as a strategic area situated in a locality called ‘Cajón del Maipo’. This is a canyon which lies in the southeastern Andean region of the Metropolitan Region of Santiago, Chile. ‘El Morado’ is a glacial cirque which is part of the most relevant hydrographic system of the Metropolitan Region in the country. The whole system can be represented by the essential role of the Maipo River basin. To give more context about the geographical location and the relevance of the Maipo River, I provide further information from the documents I analysed, trying to understand the important

[2] All quotations from the Management Plan are translations made by myself from the original Spanish.

connection of the system ‘veins of Santiago’ (see Figure 18). This process was part of my own process of conscientisation.

Originating at the foot of the Maipo volcano, the Maipo River starts at around 5,523 meters above sea level. The Maipo River is the main river flowing through the Santiago Metropolitan Region and the Valparaíso Region of Chile. According to the Management Plan (2011), the Volcán River, a tributary of the Maipo River, flows entirely through the Andes in the Santiago Metropolitan Region. This river, along with its smaller contributing ‘veins’, serves to drain areas including the Chilean slopes of the San José Volcano and the territory encompassing the ‘El Morado’ natural monument. The basin of the Maipo River is used for drinking water. The basin is bounded to the north by the Aconcagua Basin, to the south by the Cachapoal Basin, to the east by the Andes-Argentine border, and to the west by the Pacific Ocean (see Figures 17 and 18).

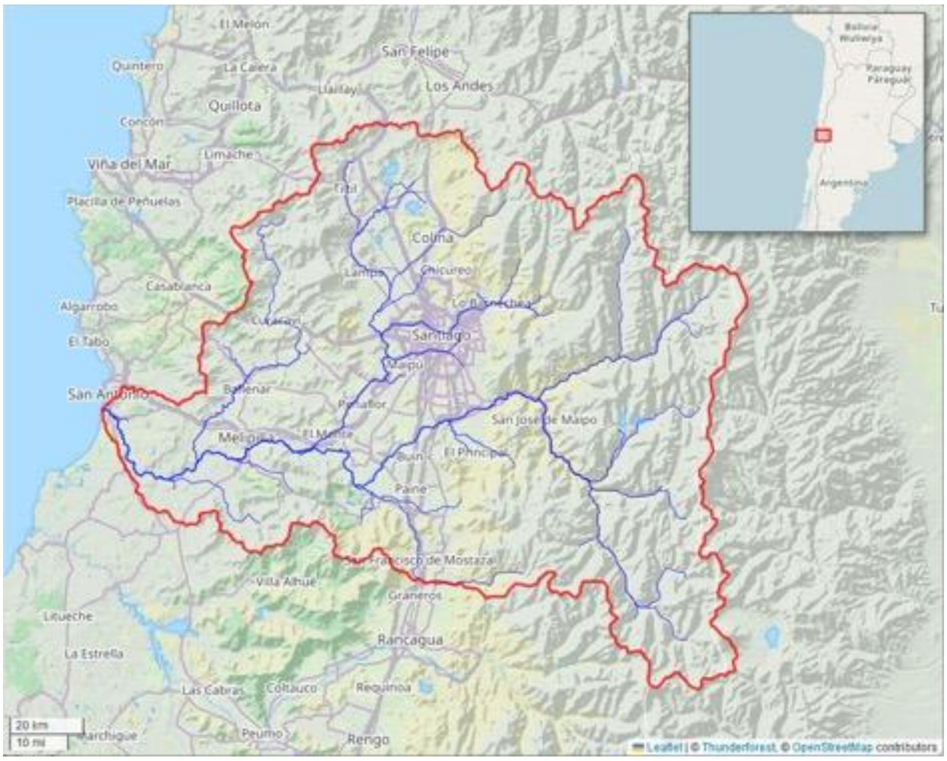

Figure 18. Analysing the tributaries of the Maipo River. Map and network of the Maipo River watershed. Created with the free Global Watersheds web app. Permalink to interactive map: https://mghydro.com/watersheds/shared/3ECB2F.html

During the first interview, Andrés highlighted that the Maipo River “serves as the primary source of agricultural irrigation for the region” (interview 1). Indeed, the river fulfils more than 70% of the demand for water in the metropolitan region of Santiago (Cai et al., 2011).

This life-enhancing role of the river stresses the importance of protecting this area and studying hydrographic and river systems in Santiago, especially considering that the population of Santiago is growing, and is estimated to reach 8.4 million inhabitants by 2024.

Other relevant points to consider when envisioning the interconnectedness between human and non-human entities include understanding that the volume of the Maipo River varies seasonally. This means that its regular flows are replenished by winter rainfall and the melting of Andean snow (Management Plan, 2011). As we can see in Figure 19, the origin of the river is indeed in the glaciers of the Andes Mountains, where many of them are in San José de Maipo. The Maipo River basin covers approximately 15,000 km^2. Its main tributaries rivers are the Colorado, Yeso, and Volcan Rivers, with the latter receiving contributions from the Morales stream located within the 'El Morado' natural monument, which crosses it from north to south (Cai et al., 2011). In the upper course, other small tributaries such as Popeta, El Sauce, and San Juan also flow into the Maipo River. Finally, after a journey of 250 kilometres, the Maipo River empties into Llolleo, just south of the port of San Antonio (Valparaíso Region), and then into the Pacific Ocean (see Figures 19 and 20).

Figure 19. The mouth of the Maipo River in the Pacific Ocean at San Antonio, Valparaiso. This area is used as a nesting, feeding, refuge, and resting site for aquatic, terrestrial, migratory, and some marine birds. During summer seasons, average daily counts of birds range from 4,500 to 5,000, with peaks at times reaching up to 17,000 birds per day in the same period. (Source: Andres Bertens)

According to Cai et al. (2011), based on national agriculture and environmental policies in Chile, the Maipo River Basin has been selected as a case study site by numerous economists and policymakers due to several factors. First, there is a rising demand and competition for water among agricultural, domestic (urban), and industrial uses (see Figure 20). Secondly, there are growing concerns regarding the efficient, equitable, and sustainable management of such demand. Thirdly, there is an increasing worry about water pollution stemming from agricultural, urban, and industrial mining activities. Lastly, there are innovative water management and allocation policies in the basin, including markets for tradable water rights. Chile stands out among ‘developing’ nations for its use of market-based instruments for water allocation, which have also been considered in other developing countries (Bauer, 2013).

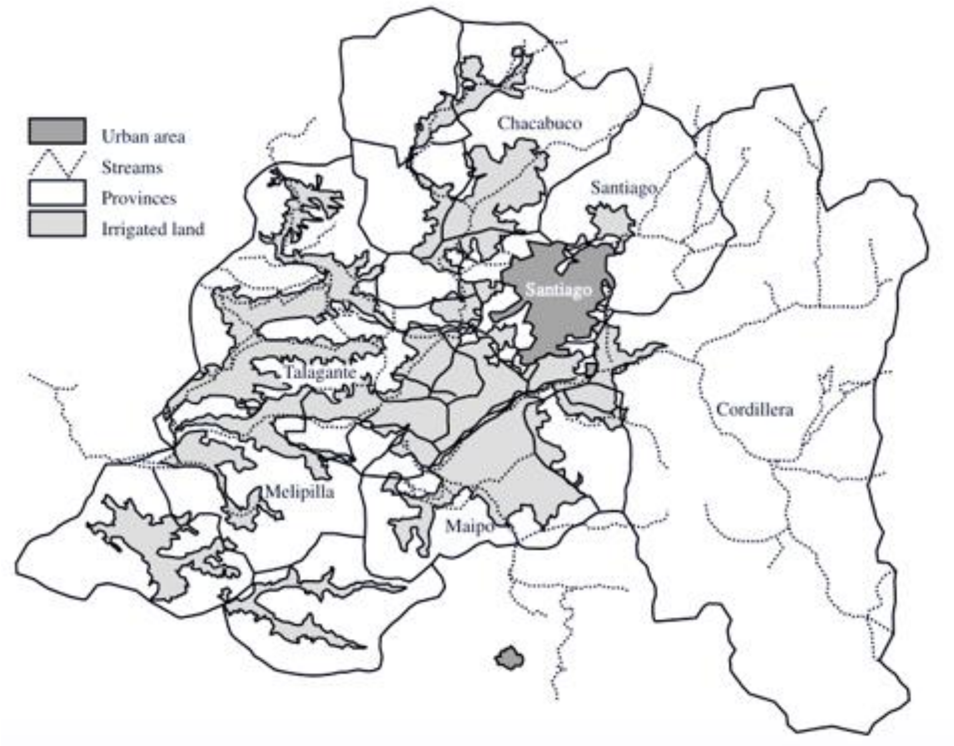

Figure 20. Geographic and administrative features of the Maipo River Basin. Irrigated agricultural areas. (Source: Cai et al., 2011)

Market-based instruments were installed during the privatisation of water sources in Chile during the dictatorship of Augusto Pinochet (1973-1990) (Mundaca, 2020). The 1980 Constitution enshrined the private ownership of water, a policy that continued and was even intensified following the democratic transition, including the privatisation of sanitation as a process of neoliberalisation of nature (Villavicencio, 2021). Since then, Chile has become known as the world's leading example of the free-market approach to water law and economics – being called 'the textbook case' of treating water rights not merely as private property but also as a fully marketable commodity (Bauer, 2013). The Chilean Water Code, introduced under Pinochet's Constitution, grants secure transferable and perpetual water rights (Mundaca, 2020). These rights typically take the form of proportional rights over a variable flow or quantity. They can be consumptive or non-consumptive, which means the water must be returned to its original flow after using it or not; permanent or contingent, continuous or discontinuous, and may rotate among multiple individuals (Cai et al., 2011). In practice, today, the Suez group, Aguas de Barcelona, Marubeni, and the Ontario Teachers' Pension Fund control fully 90% of the drinking water supply in Chile (Mundaca, 2020). In 1981, the Water Code declared water to be a national resource for public use but also an economic asset. According to Mundaca (2020), Chile has fully privatised water, which means that this 'resource' is understood as a private good. This view is institutionalised in the Chilean Constitution to this day.

In my view, the current constitution in Chile has taken on the task of protecting and endorsing market abuses and considering water as just another product to be exploited, marketised, monetised and commodified. Therefore, the character of Chile's economic model and its legal and institutional structure generate effects of great magnitude in different territories, while also producing structural, socio-ecological, and cultural inequalities and injustices.

As evident from the description of the geographical and political context of the natural monument and the Maipo River, there exists a strong interconnection among various entities and great opportunities to promote critical approaches for scientific and environmental literacies. For instance, exploring the origin of the Maipo River during a visit to 'El Morado' could disclose highly relevant topics addressing the significance for nature as well as the intricate networks of human and non-human entities existing from the Maipo River's source until its opening in the Pacific Ocean. Analysing the complexity of the hydrography of the metropolitan region offers various opportunities to discuss the relevance of rivers. In particular, when visiting the park, Andrés and Humberto highlighted the opportunity for visitors to see the source of the river from the glacier and understand how this river is part of a network, which is part of a complex interconnected system on which the local species, as well as those along the entire course of the river, depend. From outdoor education, analysing the significance of the Maipo River and the drinking water matrix, essential for both human and non-human entities, could be an initial step to promote scientific and environmental literacies by digging into various factors such as hydrological networks, environmental regulations, and the significance of protecting ecosystems as presented around 'El Morado'.

For students and others – including pre- and in- science teachers – visiting 'El Morado' could provide a valuable empirical and sensory experience to expand what is learned in science to the social, economic, ethical, and political implications. For example, after listening to Humberto's stories about hydrological system of the Maipo river basin, I asked pre-service teacher to reflect and imagine about potential questions to discuss with students when visiting 'El Morado'. Andrea and Antonia started mentioning some preliminary thoughts and then, after the visit, I asked them to write collaboratively some potential questions for their future students hypothetically visiting the park. Some of the questions were about simple identification of species but some of them were also based on protection and interconnected systems:

- Why do you think it is relevant to protect the river?
- Where does the Maipo River originate and where does it flow to? Draw a map showing the interconnection of the different rivers in the basin.
- What is the function of the river for the ecosystems and human and non-human entities that live because of its existence?
- What species do you identify during the visit to the park?
- Which of the species you mention would be at risk if something were to happen to the river?

These pre-service teachers' questions are crafted to cultivate a profound comprehension and critical thinking about the significance of river ecosystems, extending beyond mere scientific aspects to encompass environmental literacies. For example, the first question motivates students to consider the multifaceted roles that rivers fulfil within the environment, economy, and society, potentially inspiring discussions about ecological balance, biodiversity, and human dependency on natural ‘resources’. This process might promote a comprehensive understanding of environmental responsibility. Additionally, asking about personal perspectives makes the issue more tangible, prompting students and teachers to reflect collectively on ethics and values about the broader consequences of environmental degradation.

The second question aims to enhance geographical and ecological understanding. It necessitates knowledge of physical geography and hydrology, highlighting the interconnectedness of water systems and the influence of a single river on a broader ecological network. Mapping exercises encourage spatial thinking and underscore the complexity of watershed ecosystems. Furthermore, this approach aids in visual learning, assisting in grasping the physical extent and interconnectedness of ecosystems, and may reveal the impacts of human activity on natural watercourses. Andrea and Antonia’s insights are also opportunities to connect with the arts and other forms of producing information and showing findings.

The third question invites contemplation of the river’s ecological functions, including habitat provision, water purification, and nutrient cycling. It also draws attention to the concept of ecosystem services – the benefits nature provides to humans – encompassing cultural, provisioning, regulating, and supporting services. Reflecting on the holistic environmental impact by considering both human and non-human entities, this question encourages an appreciation of biodiversity and the interconnectedness of life and underscores the vital role rivers (and their tributaries) play in maintaining ecological balance and supporting biodiversity. Thus, those questions are showing opportunities for scientific and environmental conscientisation.

6.1.2 Observation as a way to cultivate an emotional connection with nature

Humberto mentioned that the park rangers frequently receive enquiries about species identification. Actually, during the interactions while we were walking, Humberto often took on a leadership role about observation, perhaps from his position as an expert guide or environmental educator. In some of the interactions and dialogues I recorded (shown in the following photographs) he mentioned various geological structures around the landscape we were observing, pointing out the name and elevation of each of the mountains that could be seen (see Figures 21a, 21b, 21c, and 21d). Antonia recalled this special moment by saying:

This experience was very rewarding on a personal level. I had never before had the opportunity to observe in detail a landscape like this. Humberto looked very happy that day doing his job. His enthusiasm was very gratifying, and he passed his energy on to us. In general, the teamwork during the ascent was very enjoyable. I feel that a trip to El Morado can be very beneficial. There is so much to analyse, historically and chemically. Looking at the rocks, I was reminded of the chemistry labs, where we talked about the colours of the elements, but now I was seeing them alive, in nature.

During these instances, there were many questions about the types of rocks, minerals and species present in the area, migrations, and the geological processes that have shaped the natural history of the park. When we talked about ecosystems, the various interactions Humberto mentioned resonated with the teachers regarding the importance of the experience and learning in contexts where one can see, but also feel, hear, and connect in various ways. In these instances, we concretely discussed how to approach such observation tasks with students and how one can learn about various topics proposed in the science curriculum.

Figure 21a. Observation by participants during the visit to ‘El Morado’; Figure 21b. Observation of geomorphology of El Morado. Figure 21c. Dialogue and collaboration during the visit to the park; Figure 21d. Trekking at ‘El Morado’ with participants. (Source: Gonzalo Guerrero)

By incorporating explicit tasks of observation of species into outdoor education, students can develop a deeper understanding of ecological concepts and the importance of biodiversity conservation (Okah-Tim, 2023). This hands-on approach to learning can also enhance student motivation and engagement, particularly in the context of outdoor and experiential learning experiences (Mann et al., 2023). Lastly, linking the observation of rocks, minerals or species to potential conservation risks underlines the fragility of ecosystems in the face of environmental shifts. For example, the collective reflection during the visit to ‘El Morado’ promoted some discussion about how pollution, habitat destruction, climate change, and other human-induced factors affect biodiversity in the park. This reflection opened possibilities for discussions on the vital need to safeguard habitats to maintain biodiversity. In my view, grasping the immediate effects of environmental hazards on particular species in the park can motivate visitors to engage in conservation efforts and adopt critical views of the whole interconnected system.

Particularly when visiting ‘El Morado’, identifying species during a pedagogical field trip can significantly enhance different understandings of local ecosystems, the diversity of life forms supported by the river, and the importance of conservation efforts to protect these species; in addition, this process can raise awareness and foster appreciation for biodiversity. This direct engagement with the environment not only promotes observational skills but also cultivates a personal and emotional connection to the natural world, leading to a deeper appreciation of its complexity and beauty (Eyster et al., 2022; Bele & Chakradeo, 2021). By observing and identifying different species, visitors can gain insights into the intricate relationships within the ecosystem and the significance of biodiversity conservation efforts. Moreover, such experiences can enhance learner engagement by making learning more psychologically and emotionally meaningful (Noe et al., 2010). Engaging with nature in this manner can also have positive effects on mental health and well-being. Exposure to natural sounds in parks has been linked to health benefits, and parks that feature high audibility of natural sounds get more visits (Buxton et al., 2021). In this sense, the visit to the park offered a deep sense of nature contemplation which was summarised by participants at the end of the visit with the word ‘majesty’ as a way of sensing, believing, and experiencing that we are part of nature and coexisting with it:

> Particularly, ‘El Morado’ contributes to that connection to nature, which I believe we, as scientists, are silencing. To be honest, after visiting the park, I realised that we are super disconnected from nature. The visit made me think about how important it is to feel part of nature. This feeling was strong while visiting ‘El Morado’. I felt so small. It is a place where the flora and fauna are more explicit, so to speak. What impressed me the most was the mountain; it was so imposing, majesty! Finally, the feeling that there are other living beings, I feel that it also puts us in a place of reflection about our position in the world. (Ursula)

> I felt like there was a beautiful coexistence; I felt that in that place it did not matter where you came from, or who you were. I felt a sense of harmony, a harmony with nature that I cannot fully explain. It originated from the fact that we all shared a common goal: to benefit from that educational outdoor activity. I also sensed a harmony that might not have been present in other settings, such as a science classroom or a meeting room. (Angelica)

Visiting the park gave us time to observe ourselves in the position of the immensity of the park and reflect closely and sensitively about our position as human beings. In this regard, studies have shown that nature-related activities can lead to fostering a sense of expansiveness, interconnectedness, and a broader perspective on life (Naor & Mayseless, 2021). This point was further emphasised by Humberto, who mentioned that ‘El Morado’ is becoming an increasingly popular destination for ‘Nature Therapy’, particularly through the practice of Shinrin-Yoku or ‘forest bathing’ (interview 1). The literature, including studies by Hansen et al. (2017), emphasises the extensive health benefits that exposure to nature and green environments have on human physiological and psychological systems. Song et al. (2016) have documented how such practices can significantly reduce the stress and technostress experienced by many people living in capital cities. This body of research highlights the role of Shinrin-Yoku as a set of practices aimed at achieving ‘preventive medical effects’ by engaging with natural stimuli. These interactions might facilitate a state of physiological relaxation and enhance the body’s immune functions, thus preventing various diseases. Therefore, visiting ‘El Morado’ can also play a key role in maintaining and improving visitors’ health in our increasingly digital and urbanised lives.

Building on the afore-mentioned insights, the concept of emotional literacy finds a natural ally in the practices of Shinrin-Yoku, as exemplified by visits to places like 'El Morado' for a kind of 'nature therapy'. Emotional literacy, as discussed in Chapter 3, offers a profound opportunity for individuals to connect with their inner selves and the surrounding natural world, fostering a deeper awareness and articulation of emotions. Regarding emotional connections and opportunities for emotional literacies as part of critical approaches to literacies, Ursula had several insights in the final interview after visiting the park:

> I believe that learning outside the classroom is also founded upon some motto. It positions you; I think it is the quickest way to contextualise and anchor knowledge about science to something more significant for the student. Therefore, from this, we can generate a bond, because one can say to our students: "Look, that is where the drinking water we consume comes from".
>
> Learning outside the classroom places scientific learning in a geographical location and then gives you the possibility of feeling that this learning is 'real'. But at the same time, it opens up questioning what is not real because I believe that the vast majority of things learned in school are detached from reality. The majority of the topics in science have nothing to do with my life, nor am I interested in it, so, from that perspective, first, it kind of anchors you, I believe, to reality. There is something special about placing nature or the understanding of nature into something real, tangible, that one touches, sees, smells, and hears. This is also different, as well as experimenting in the lab. But another different thing is like a spiritual dimension, something like that, like an illusion that is intangible, and that has to do with another dimension that is also very little addressed within the science classroom. Learning outside the classroom provides you with that spiritual sensation, which is not a model or a scientific representation. It is a sensation, a feeling.

In the context of Ursula's emphasis on learning outside the classroom, ontology becomes an important consideration in both science and environmental education. Her focus on connecting students to the real world through experiential learning raises questions about what is considered 'real' in the process of teaching and learning science. Ontologically, this approach challenges the boundaries between theoretical concepts discussed in the classroom and the tangible, observable elements of nature encountered outside. Contrasting with the detached nature of traditional schooling, she highlights how natural experiences, such as those in 'El Morado', deeply connect students to nature and what is real, inspiring respect and a feeling of unity with the environment. In this sense, outdoor education, and particularly the visit to 'El Morado', not only brings scientific concepts to life but also weaves in an emotional and spiritual insight often overlooked in science classrooms. Ursula suggests that encounters with nature offer a profound spiritual awareness, enriching education by making it more engaging, relevant, and spiritually enlightening. Ultimately, she advocates experiential learning as essential for education, bridging academic knowledge with real and tangible life aspects, thus helping students understand the world and their place within it more holistically. Moreover, about the visions of scientific literacy which Ursula knew very well as a science educator, she raised a relevant reflection about some of the traditional approaches to scientific literacies and the so-called *Vision III*:

> I believe there is a dimension that kind of does not appear in the pyramid of *visions* of scientific literacy [by Sjöström and Eilks, 2018] which is the emotional dimension, and I believe education outside the classroom can add that ingredient.

Collectively, the questions and insights raised by all participants aim to deepen diverse understandings of the complexity of river ecosystems and encourage critical discernment about environmental issues, the interconnectedness of human and ecological systems, and the importance of individual and collective action in conserving 'natural resources'. Those questions are in line with the goals of critical scientific and environmental literacies, as summarised in Chapter 3, which include informed decision-making, ethical reasoning, emotional literacies, and a commitment to tackling environmental challenges and potential socioenvironmental conflicts. Additionally, there is potential for acknowledging the inherently political nature of literacy, with an emphasis on questioning power structures (Freire, 1979) and advocating socio-ecological justice in the production of scientific knowledge and environmental practices (El Halwany et al., 2021).

6.1.3 Dialectics of nature

The visit to the park, as highlighted in the preceding paragraph, not only provides an opportunity for exploration, observation and contemplation but also initiates a discussion on the dialectics of nature. This process serves as a crucial step towards conscientisation, as it prompts an examination of the interconnectedness and evolution of natural phenomena, viewed through the prism of contradictions, conflicts, and their resolutions (Engels, 2012). For example, analysing the hydrological system in Santiago provides a platform to critique the privatisation of drinking water in Chile and its implications for environmental management. Such analysis points out disconnections between conventional definitions of scientific and environmental literacy and the pressing global issues, often aligned with neoliberal economic agendas. The analytical reflection process of scrutinising the privatisation of water in Chile open pedagogical possibilities to integrate socio-political and economic dimensions in science and environmental outdoor education. Moreover, it brings opportunities to empower individuals to engage in democratic decision-making processes concerning environmental matters, advocating for social inclusivity and challenging dominant narratives (Hodson, 2011).

Finally, I would like to highlight that examining the river case and the risk of damaging 'the veins of Santiago' demonstrates the potential to understand literacy as a collective endeavour (Roth & Barton, 2014), emphasising the importance of dialogue, collaboration, and community engagement in addressing environmental challenges. Additionally, the river case prompts reflection on the meaning of sustainability within the context of a neoliberal agenda in Chile, where even water is a marketable commodity.

6.1.4 Interdisciplinarity as an essential dimension for critical literacies

Studying interactions within the park and broader connections with other structures such as hydrological systems could provide valuable understanding that could contribute to science education across multiple disciplines. Indeed, when asked what opportunities do you think 'El Morado' offers for an educational field trip? Humberto and Andrés effectively addressed the potential for interdisciplinary learning based on hands-on experiences. Humberto defined 'El Morado' as a small scientific laboratory:

> 'El Morado' is a 'small' laboratory, a scientific area, a very small scientific laboratory, where you can benefit greatly, not only in terms of chemistry, physics, and biology. Many visitors, such as schools or universities, also come to talk about history, geology or geomorphology. Besides, there are opportunities for archaeology, painting, photography, physical education, and mathematics, and they link it all with this protected area. Nowadays, protected areas like 'El Morado' are an opportunity for social, cultural, economic, or scientific development, and obviously, everything is interconnected.

Similarly, as Humberto mentioned, I can see different opportunities for inter and transdisciplinary science and environmental education which, as I noted in Chapter 3, can be relevant for the promotion of critical approaches. For instance, through the lenses of geography, visitors and students in pedagogical activities could examine the location and characteristics of rivers within the terrestrial landscape of the Maipo basin. Ecology could help in analysing river ecosystems and the interactions among organisms inhabiting them and their surroundings. These local interactions can be observed starting from the visit to 'El Morado'. From geology, teachers could investigate the formation of river channels and the associated processes of erosion and sedimentation. Also, from archaeology, the location of the mountains offers an inspiring reflection from fossils (some of them are visible in the park) about what this place was like millions of years ago (see Figure 22). I can see valuable elements for addressing a critical approach to STEM topics (from non-hegemonic approaches), such as hydraulic engineering, which focuses on the design of river-related infrastructure like dams and channels. Lastly, in terms of education for sustainability, the management of water resources could be analysed from a critical lens. For instance, what measures are necessary for the sustainable management of rivers for water supply, agriculture, and other human uses? Who are the companies and network of actors behind the control of water supply in Santiago?

Figure 22. Ammonites from the Upper Jurassic – Lower Cretaceous are abundant and well-preserved around the zone of ‘El Morado’. These fossils are sedimentary successions of the central Chilean Andes, known as the Lo Valdés and Baños del Flaco Formations. (Source: Blacklights)

Concerning the natural history of the area, Humberto mentions the value of studies related to geology which can contribute to the discussion about colonisation in Latin America and particularly in Chile. At the same time, he mentions some questions or strategies for studying indigenous communities that inhabited this region of the country before Spanish colonisation:

> In this place, there is a lot of diversity in rocks. So, you can take a rock and ask a child about the origin of that rock. You can explain to them, for example, what happened 18 million years ago in this place. What happened with the glacier as it retreated and how it formed the place? This place has a history. The history of our past. It has a history of the first humans who inhabited this area but also what happened with the first tribes that

> lived here. The main indigenous group who lived here were the Chiquillanes. Nomadic peoples traded furs with the first settlers who lived here before colonisation.

Andrés mentioned that in ‘El Morado’, students could study the underground aquifers and other sources of water. He also mentioned that in ‘El Morado’ there are around 45 species of migratory birds, such as condors, eagles, bacon-eaters, and Andean parrots. Moreover, ‘El Morado’ is the home for more than 300 species of plants. In this small valley, there are many local species (see Figure 23). The particular role of the condor and snakes are highlighted by park rangers as entities to promote awareness about interconnection with other species:

> Here in this area, there are condors. These species are very important in ecology, for cleaning. When an animal dies, they clean the place. You also find snakes (long and short-tailed), lizards, and amphibians (toads, rolling toads), which are important for pest control (flies, mosquitoes). In the 1980s, there was a boom in exporting species from Chile. Many snakes, frogs, and lizards were exported, and there was an increase in the number of mosquitoes because the number of natural predators decreased. So, that tells us a lot about how all species are very important. From there, you can work in environmental education. You can work with the sciences, ornithology, and countless other things. This is a living laboratory. (Humberto)

> If a child tells me, for example, “Look, a snake”, I can tell them that this animal directly benefits them. “And why?”, the child might ask. Because that animal is a natural pest controller. If you kill that animal your house can be full of flies in the future. So, they can make the connections. If you have fruits, it’s because there is a plantation, and if you kill those snakes, you won’t have pest control over that fruit. Therefore, more pesticides or insecticides will be used to control that pest, or perhaps you won’t have options to eat that food anymore. That’s how we connect it and that’s environmental education for us. Connecting everything, the natural world, with the simple things you do in your everyday life. (Andrés)

The perspectives shared by Humberto and Andrés exemplify how interdisciplinarity is a key element to promote conscientisation and critical scientific and environmental literacies. For instance, emphasising the vital ecological functions of local wildlife – such as carrion birds that aid in decomposition and reptiles and amphibians that regulate pest populations – they highlighted the intricate balance of ecosystems and the consequences of disrupting them. But also, Humberto referenced historical instances where the removal of native species led to an increase in pests, illustrating the unintended consequences of human actions on ecological systems. This scenario encourages visitors to critically examine the impact of human activities on the environment, but also reflecting on other dimensions and subjects such as history, agriculture, economy, chemistry, etc.

Andrés builds on this by demonstrating how teachers and they themselves as park rangers can facilitate connections between visitors' observations and broader environmental and scientific concepts. For instance, he seizes the opportunity to explain the park's role in controlling pests that could otherwise harm agriculture or increase reliance on chemical pesticides. This narrative might help students to link everyday experiences with complex ecological relationships, fostering a deeper understanding of how natural processes directly affect their lives and the live of non-human entities. This linkage not only contextualises socio-environmental challenges but also allows students to explore how historical events shape contemporary issues, fostering a nuanced perspective that supports informed decision-making and responsible environmental stewardship.

Reflecting on this approach, I find it deeply gratifying to witness in-service and pre-service teachers listening and paying attention to Humberto during the visit, as they come to understand the complexities and interdisciplinary dimensions of socio-environmental issues. When they mentioned the connections between scientific knowledge and socio-environmental conflicts, I see opportunities to transform scientific literacy perspectives and foster a genuine sense of agency. For me, this give emphasis to the importance of conscientisation in environmental education – it is not just about imparting knowledge but also about nurturing empathy, responsibility, and empowerment that can inspire positive, informed action.

In this regard, Andrea pointed out some relevant ideas about how to organise an outdoor activity considering an interdisciplinary approach:

> The planning of the outdoor activity would be easy to integrate in an interdisciplinary way into other subjects. I believe that especially in language (Spanish subject), which is constantly seen in high school connected with mass media topics. So, something quite nice would come out, honestly. I imagine, perhaps, we could do intermediate activities, like introducing the topic of environmental issues and the effects of climate change, being able to go to 'El Morado', specifically, to identify issues that occur in the area and perhaps, this might be very ambitious, but link it with the problems that happen

> here in Santiago, because, after all, our major water source is the Maipo River, which comes from there. Often, including myself, we do not consider what happens in the mountains because we are accustomed to urban life conditions. It seems as though they are two isolated sectors, but a thorough analysis of the entire situation might lead us to reflect on the balance and harmony, which are crucial to consider. (Andrea)

Reflecting on Andrea's perspective, I recognise a significant potential in integrating outdoor activities into an interdisciplinary curriculum, particularly by linking environmental education with other subjects. Planning such activities feels not only feasible but also highly enriching across various school subjects. Organising an interdisciplinary visit to El Morado might enable students to investigate local ecological concerns firsthand, deepening their understanding of environmental issues like climate change and water scarcity.

From Andrea's insight, this approach promotes conscientisation by encouraging students to critically examine the connections between urban life and natural ecosystems. Realising that our primary water sources originate from the Andes, for instance, can prompt a deeper appreciation of environmental balance. Often, we overlook what happens beyond our urban surroundings, treating natural and urban areas as separate entities. Facilitating a thorough analysis of these interconnected systems might lead students to reflect on the importance of harmony between them.

Empathy towards nature is a clear step for critical approaches and interdisciplinary perspectives to break down the silos between subjects and disciplines. Indeed, Andrea aims to prepare students to transition towards a conscientisation process. Despite recognising how ambitious it might be to link distant geographical challenges to the city where students are living, she believes in the feasibility and necessity of such interdisciplinary projects to develop a comprehensive understanding of environmental issues as a whole and as a complex, interconnected system.

Figure 23. Examples of local fauna at ‘El Morado’: Grey-hooded sierra finch (*Phrygilus gayi*), Andean fox *Lycalopex culpaeus*) and Andean condor (*Vultur gryphus).* (Source: Blacklights)

6.2 A monster in the park

Unfortunately, 'El Morado' and its surrounding areas are currently experiencing the adverse effects of climate change and particularly the devastating impact of global warming. According to park rangers' accounts during the interviews:

> In winter, rainfall reminiscent of the 1980s is almost a thing of the past; during the summers, temperatures frequently exceed 35 degrees Celsius; and seeing wetlands and rivers with substantial bodies of water throughout the year is increasingly rare. (Andrés)

However, the threats to this region and its biodiversity extend beyond the impacts of climate change. The entire basin of the Cajón del Maipo has also long suffered from persistent exploitation and systematic extractivism. In the early colonial period, the valley and basin of the Cajón del Maipo became focal points for settlement and Spanish colonisation. Following the establishment of San José de Maipo in 1762 to support mining at the San Pedro Nolasco silver mine, the area underwent rapid deforestation to meet the demand for firewood and timber. This timber was essential not only for construction and heating homes but also for supporting mining and other extractive activities. Additionally, the introduction of traditional transhumance[3] livestock farming, involving seasonal movement between summer and winter pastures. This process further diminished the vegetation cover and altered the soil structure, thus transforming the landscape into what we see today. These processes have led to continual changes in the landscape.

Moreover, today 'El Morado' and the Maipo Basin are being impacted by a monster in the park, the environmental conflict known as 'Alto Maipo'. Thus, as part of my/our conscientisation process and with the aim of developing and organising the outdoor science activities at 'El Morado', I initially began to establish a network of human and non-human entities to understand in more depth the origin of this 'monster in the park'.

This process began with initial interviews and dialogical seminars, followed by the design of an actors' network. Participants then collectively helped gather additional information and doing research from the socio-environmental conflict map developed by INDH, Chile, and the EJ Atlas. These networks could potentially serve as educational resources to support outdoor activities at 'El Morado' and foster processes of conscientisation. Furthermore, to gain more context about the project, I interviewed environmental activists from the

[3] Transhumance refers to the seasonal movement of people with their livestock between geographical or climatic regions.

Coordinadora Ciudadana No Alto Maipo (CCNAM), who provided crucial insights. The results of these phases were discussed with the group, helping to conceptualise an alternative network that could mitigate environmental conflicts and opportunities to imagine opportunities to develop a way to promote scientific and environmental literacies approaches through outdoor education. The goal of collecting more information about Alto Maipo was to achieve a better understanding of the environmental conflict affecting ‘El Morado’ and to analyse the interconnections among various entities. After the first dialogical seminar, we summarised and scrutinised the complex network of actors linked to Alto Maipo.

6.2.1 The origin of the monster

The Alto Maipo hydroelectric power project (Alto Maipo, hereafter) started in 2007 and it was developed by AES Andes S.A., formerly AES Gener SA, a subsidiary of the second most extensive North American energy company, AES Corp (Folchi & Godoy, 2016). In 2011, AES Gener and Aguas Andinas (the largest sanitary company in Chile) signed an agreement to divert the water destined for water supply for the city of Santiago so that it could be used in the hydroelectric project (Chile Sustentable, 2020). To the present day (July 2024), Alto Maipo is still under construction/reparations outside Santiago at San José de Maipo; it is being executed by STRABAG SpA Chile (an Austrian-based technology company with nearly 5,000 employees from over 20 nations) and aims to operate fully at some point in 2025. The project is intended to channel the water of the Maipo River, and the main ‘veins’ of the Maipo River (as presented in the previous section) into a system of tunnels. This channelling process of water would leave a very low ecological flow volume in the river, inadequate for sustaining much of its current life (Godoy, 2014). The associated infrastructure involves two run-of-the-river centrals and 70 km of abduction tunnels 6-8 m in diameter (see Figure 24a). The system of tunnels can be considered as a big ‘monster’ who literally sleep below the Andes Mountains and exactly underneath ‘El Morado’ and the San Francisco Glacier, as shown in Figure 24b.

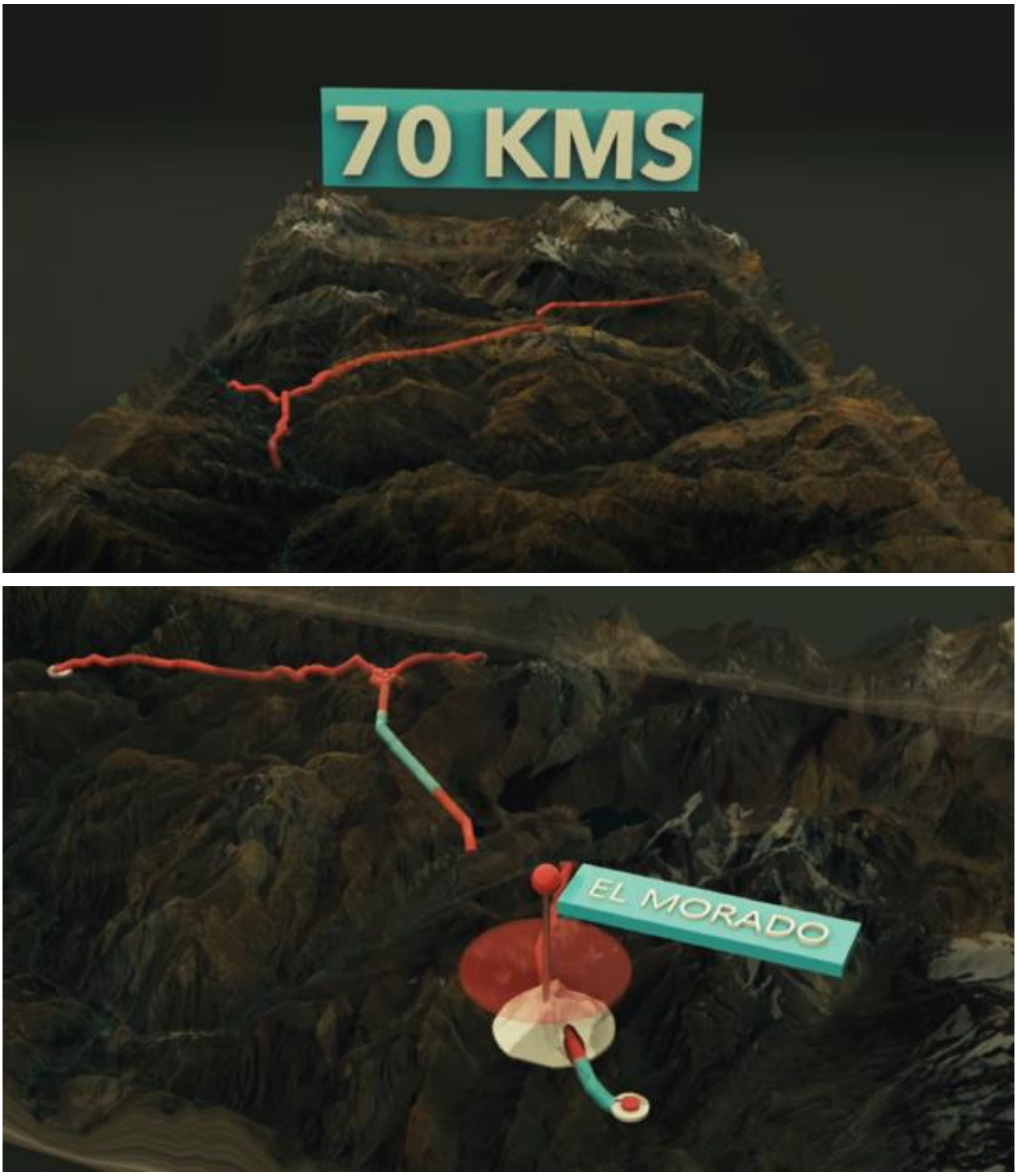

Figure 24a. System of tunnels of Alto Maipo. Figure 24b. ‘El Morado’ natural monument and Hydroelectric Power Station, Alto Maipo. (Source: Defiende Maipo)

The project will channel the water of the principal veins of Maipo river – Rio Yeso, Río Colorado, and Río Volcán (see Figure 25) – to power two generators (Alfalfal II and Las Lajas) and return it to the river downstream (Bnamericas, 2020) (see Figure 26).

Figure 25. System of tunnels and the process of water collection from three different rivers: Río Colorado, Río Yeso and Río Volcán.(Source: Defiende Maipo)

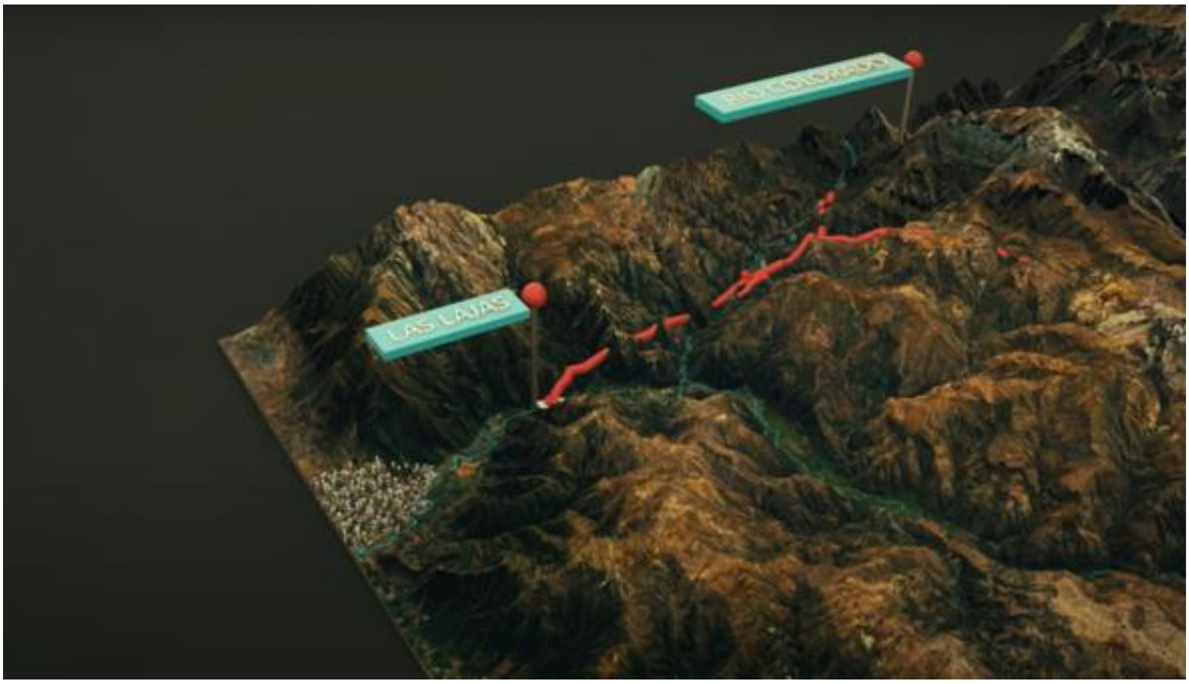

Figure 26. Point of return of water in ‘Las Lajas’ after using the river water in the Alto Maipo hydroelectric project. Santiago City can be seen also in the picture.(Source: Defiende Maipo)

Alto Maipo threatens the water supply to over eight million Chileans (42% of the Chilean population), and it might have devastating long-term environmental impacts (Folchi & Godoy

2016). Originally, Alto Maipo was projected to cost US$700 million[4] and be completed in 2013 but it has had challenging financial plans and timetable overruns. The Inter-American Development Bank (IDB) signed a $195 million loan agreement with Alto Maipo Spa, owned by AES Gener (60%) and Antofagasta Minerals (40%), as part of a financing package of more than $1.2 billion (Fitzmaurice, 2014). Antofagasta Minerals is owned by Grupo Luksic, which is one of Chile's most significant business conglomerates, with $71 billion in assets under management and founded in 1957 by Andrónico Luksic (Fitzmaurice, 2014). The Los Pelambres mine, part of Antofagasta Mineral, held until 2019 a 40% equity investment in Alto Maipo. The Los Pelambres mine is a copper mine located in the north-central of Chile. It is one of the largest copper reserves in the world, having estimated reserves of 4.9 billion tonnes of 0.65% copper ore (Minera Los Pelambres, 2018). The installed Alto Maipo capacity is 530 MW, but the power generation capacity is 160 MW. This energy is intended to travel to Minera Los Pelambres in the north of Chile (Minera Los Pelambres, 2018).

The project is also co-financed by the International Finance Corporation, and the US Overseas Private Investment Corporation (Folchi & Godoy 2016). Alto Maipo negotiated amendments to the project financing documents with a syndicate of international development banks, Overseas Private Investment Corporation (OPIC) and International Finance Corporation (IFC), and Chilean and international commercial banks, which increased the project financing to approximately $3.05 billion, 60% in debt and the remaining 40 per cent in equity (Bnamericas, 2020). Moreover, Alto Maipo is being financed by nine banks and was approved, despite severe flaws in the environmental impact assessment and inadequate consultation (EJ Atlas, 2024). Like most high-cost projects, Alto Maipo requires economic articulation with foreign investors. Thus, Alto Maipo depends on large investment groups and national and foreign banks. Its financing is closely coordinated with global capital. The network of national and international actors such as institutions, banks, global corporations and significant subsidiaries and associate companies, part of the Luksic conglomerate (Grupo Luksic), can be summarised and distributed in a network of actors (see Figure 27).

[4] All data about costs/prices are in US dollars.

Figure 27. Network of actors and institutions supporting Alto Maipo. (Source: Gonzalo Guerrero)

As a way to get more context about the project, I interviewed environmental activists of Coordinadora Ciudadana No Alto Maipo (CCNAM). One of them commented about Alto Maipo:

> With Alto Maipo, there is a serious impact on the underground water system. So, what have the technocrats done? They showed us a computer and told us, “Look, here goes the surface water, and here goes the groundwater” and they never relate the two, because that’s what neoliberalism has done, exposing nature, exposing people, the development of people as if they were individual entities, not as a whole, not as a dynamic and fortuitous circuit, you know, wonderful, so, no, if we affect the underground system, nothing will happen to the surface system, lies, we knew that was not true, and think, even though we supply 80% of the water to Santiago, there are many neighbours here who have deep well water systems, from the springs. (Activist CCNAM)

Then, when I asked the coordinator of No Alto Maipo about the reasons that led to the existence of this project, she replied:

> Alto Maipo was environmentally assessed before the institutional framework we know today existed. There was no Ministry of the Environment, no Ministry of Energy, no Ministry of Environmental Health; it was like the first law we had for environmental impact assessment. Among other things, the owner of Alto Maipo, AES Gener, a

> subsidiary of AES Corp, the second-largest electric company in the United States, always managed to conduct a quite effective lobbying with the authorities administering the state. In other words, Alto Maipo was classified as a project of national interest, hence shortening the environmental assessment process, and increasing the chances of project approval. It was an energy context in which, if more electric generation plants were not installed, we would not become a sustainable and developed country. (Activist CCNAM)

The activist illustrates how the Alto Maipo hydroelectric project exemplifies the neoliberalisation of nature (Villavicencio, 2019), the connection between lobby groups, corruption and extractivism in Latin America, where economic priorities and corporate lobbying can override environmental protections. The project's swift approval – facilitated by its designation as a 'project of national interest' and occurring before the establishment of robust environmental institutions – demonstrates how regulatory processes can be manipulated to favour multinational corporations. This scenario underscores the importance of promoting conscientisation in science and environmental education, fostering critical awareness about the ways in which neoliberal policies can lead to the exploitation of nature. In my view, educating individuals to critically examine the interplay between economic interests, environmental impact, and social justice empowers them to challenge unsustainable practices. Analysing critically the documents about environmental regulations in Chile, the project underwent an environmental assessment before Chile had established a comprehensive environmental governance framework, or even had a Ministry of the Environment. This lack of regulation, combined with effective lobbying by AES Gener (the project's owner and a subsidiary of a major US electric company), helped classify the project as a national interest, speeding up its approval process and minimising environmental inspection. These factors highlight significant tensions between development and environmental 'sustainability' accentuating the complex interplay of regulatory gaps and corporate influence in large-scale infrastructure projects.

The Alto Maipo case emphasises the significance of striking a balance between economic development, 'green' discourses and socio-environmental concerns to attain sustainable development. However, considering all previous connections in the network, nature and water – according to Chilean environmental regulation – are positioned within the market (Gudynas, 2018), by which various institutions and human and non-human entities intervene and participate. Most of these entities are in strategic (or dangerous) spaces or positions within the network. There are also crucial actors, such as law firms or politicians, who intervene in laws and policies of the State (e.g., lobbyists or leaders in the government). In general, any relevant actor in the process of negotiations, or agreeing or distributing money or political favours will be welcome as a gear of the network. In the development and consolidation of the network, there is influence peddling, cover-ups, corruption and, at times, obstruction of justice (Gudynas, 2018).

Controversially, the project has been also registered with the Clean Development Mechanism, again based on discourses of sustainability, through which companies can receive carbon credits for projects that reduce carbon emissions (UNFCCC, 2008). Here, we can see how an international organisation, the United Nations, is part of this network and how discourses around green policies permeate the Chilean environmental regulations within this network. The current government, therefore, is at a crossroads: whether to continue supporting an extractivist economy – nominally based on green discourses – or to start considering alternative economic and public policy options that are innovative and conservation-friendly.

Regarding the role of the State in supporting those types of projects in the region, some authors have concluded that the nature of these projects differs from traditional extractivism (Gudynas, 2018) to the extent that this process can be recognised as 'progressive' neo-extractivism (Svampa, 2019). Neo-extractivism typically refers to the practice of extracting raw materials or so-called 'natural resources' like minerals, oil, and gas, predominantly in Latin American countries. This method is frequently critiqued for its detrimental environmental effects and for perpetuating patterns of exploitation that date back to the colonial era. According to Svampa (2019), progressive neo-extractivism seeks to set itself apart by proposing to allocate the profits from these extraction operations towards social programs, infrastructure upgrades, and economic policies designed to alleviate poverty and reduce inequality. The concept behind this approach is that the government can utilise these resources to benefit the general population, instead of allowing the profits to flow predominantly to private or international companies. Neo-extractivism in the Global South constitutes a structural feature of modern capitalism. Unfortunately, the dynamics of economic growth, based on historical extractivism, neoliberalism, and a particular mode of accumulation, have increased socio-environmental conflicts in Latin America. This point is also highlighted by one of the activists:

> For me, this is a process that I would call neocolonialism, the exploitation of nature. I see that what people still struggle to understand is that nature is not solely at our

> disposal, for our benefit, but rather we need to coexist harmoniously to have a healthy future. (Activist CCNAM)

This situation with Alto Maipo, presented above, might affect local economies based on tourism around the river, flora and fauna, environmental services, climate regulation, and habitat preservation, among others. Indeed, in the most democratic green lung of the capital city, the impacts of the climate crisis in addition to the impact of Alto Maipo might be very long-lasting (Godoy, 2014). The benefits for locals are few and not substantial, for instance, internet connections which will be operative while Alto Maipo is being developed, new roads which are mainly used by STRABAG, and temporary jobs. However, in the words of one of the park rangers, this is bread for today and hunger for tomorrow:

> What happens with mining and hydroelectric projects in Chile, generally, is that they are not made known to the communities. The problem is that there are ancestral lands which are intervened and encroached upon, affecting these types of communities. Here, there already are water issues, the flow rates are decreasing, and the Alto Maipo project will have a direct influence in the future because this adds up with global warming, right? This is a little snowfall, the dwindling ice, and this adds up with Alto Maipo and other companies. This situation will directly affect the flora and fauna here, but this is not made known to the people and it is attempted, perhaps, to benefit a few rather than the entire community. What I mean by this is that sometimes, as the saying goes, "Bread for today, hunger for tomorrow". We give jobs today to the people living here in San José de Maipo, but we look to the future in about 10 or 20 years to see what will happen with the commune, it will become impoverished. The extractivist system in Chile, what is happening now, right now in our country, does not work and that is what is happening, the extractivist system, the laws themselves, the conservation laws, the laws that are in the Senate, are not good, right; they favour large companies and this is evident, and it is not just me saying this, it is noticeable, and that is why there was the revolution and social outbreak that recently occurred in Chile and that is why there is a fight because the policies of the constitution need to be changed. (Humberto)

Humberto's observations bring to light, again, how neoliberal policies in Chile have facilitated environmental exploitation by prioritising economic benefits over community well-being and ecological sustainability. Again, analysing critically his discourse in terms of intertextuality, the inadequate (and lack of) environmental legislation that benefits large corporations only intensifies these problems, leading to social inequality.

Reflecting on this, I find it deeply concerning that the voices of local communities are often disregarded in favour of corporate interests. This scenario emphasises the urgent need to promote conscientisation in education, raising critical awareness about the connections between economic policies, environmental degradation, and ecological justice. Educating individuals to critically analyse these dynamics empowers them to challenge unsustainable practices and advocate fair environmental management. I believe that incorporating these topics into science and environmental educational curricula is crucial for developing responsible citizens who can contribute to systemic change.

This systemic failure, according to Humberto, was a driving force behind the recent [2019] social unrest in Chile, illustrating widespread discontent with these policies and underscoring the need for significant constitutional and policy reforms.

This point about policies and the constitution is also highlighted by one of the environmental activists, who commented:

> In Chile, the climate emergency exacerbates the crisis that we have already caused to the territory because Chile's economic model was based on extracting natural resources as critical raw materials, exporting them, and then buying them back as manufactured goods. That model, of exploiting nature and people, is what has led Chile to this disaster and makes it more vulnerable to the climate emergency: displacement of people due to climate reasons, lack of water, and loss of jobs. Pinochet's constitution guarantees that everyone can carry out their economic activities on equal terms, and that has been the argument of the political sector opposing Alto Maipo because fundamentally, they are a very important local economic actor. (Activist CCNAM)

Using conscientisation and critical discourse analysis, this insight into Chile's climate emergency reveals connections between environmental degradation, socio-economic vulnerability, and a legacy of exploitation. Chile's extractive economic model – focused on exporting raw materials with limited local benefit – harms both people and nature, echoing Freire's call to challenge systems that reinforce inequality. The Pinochet-era constitutional guarantee of 'equal economic opportunity' can mask these inequalities, legitimising corporations like Alto Maipo while sidelining communities that suffer from water scarcity, displacement, and job loss.

The language in the activist's statement frames these injustices, revealing how historical political structures and material conditions have shaped current environmental regulation. The reference to an extractivist model highlights human rights violations, such as restricted access to water and housing, all supported by a constitution (intertextuality) that justifies these inequalities. Through a critical discourse lens, we can see how this narrative both reflects and sustains socio-economic imbalances and social practices within Chile.

Through the lens of conscientisation, we can see beyond policies to the power imbalances they uphold, especially as they intensify Chile's climate vulnerability. Critically examining how historical decisions shape present challenges, conscientisation encourages a reimagining of economic structures toward sustainability and social welfare, empowering collective action for change.

Reflecting on this, it becomes clear how essential conscientisation is in education to address complex socio-environmental issues. Recognising the systemic roots of these challenges reminds us that tackling such issues requires both knowledge and the commitment to challenge entrenched systems, paving the way for a more just and resilient society.

The question then is a bit frustrating: In a context of neo-extractivism, neoliberalisation of nature and neocolonial practices, what's the role of scientific and environmental education? About this topic, park rangers and activists highlighted the critical role of education as a collective endeavour to address the role of present and future generations:

> I believe that teachers and schools have a very important role in this regard because, in countries like ours, we have already proven that if you do not act when you take an active role in different areas of our country's activities, those who represent us and manage the state do not listen to you, and you do not have an impact. (Andrés)

According to the most radical and activist views of the interviewees:

> The best thing for the economic, extractivist, transnational power is the indifference and ignorance of the people, that is, the best way to fight against them is by searching, informing, I do not know, suggesting that new young people become environmental and human rights defenders, because now, the environmental struggle is closely related to respect for human rights. (Activist CCNAM)

Together, these insights suggest a strong belief in the power of education and informed collective activism to challenge entrenched powers and effect meaningful change, highlighting the interconnectedness of environmental advocacy and human rights. Some of the discussion and analysis of this section shows opportunities in practice to answer my third research question regarding how outdoor education can promote critical scientific and environmental literacies. This process can be done by analysing the successive economic cycles and historical or potential future dimensions of environmental conflicts. In this process, it might be relevant to discuss the roles of science and environmental educators towards conscientisation. However, this is neither an easy nor an individual task, as it requires new counter-hegemonic discourses and critical imagination in science and environmental education to protect land, water, and territories. These efforts are central to my understanding of conscientisation, viewing science as a concrete, material socio-political issue.

6.3 A glacier as a more-than-human entity to develop conscientisation

Through interviews and conversations during the trekking, the park rangers shared different stories of the tensions with Alto Maipo while navigating their everyday work. As I mentioned in the previous section, park rangers narrated the natural history of the location, including the stories of pre-Columbian peoples who inhabited and protected the area. They also highlighted the sensitivity of insects to the impact of Alto Maipo, for instance, the changes in sound and temperature of the ground which in turn has cascading effects on the entire ecosystem of the park, including the glacier. These examples highlight the limitations of relying solely on reports or environmental regulations in the short-term, without paying attention to the broad interconnected network of entities. Such reports and regulations often fail to capture nuanced effects, and overlook several concerning observations:

> Chile’s greatest vulnerability to climate change is the decrease in available water, I repeat, due to the accelerated melting of glaciers. Yet, there is still no law in Chile that protects our glaciers. Besides, the construction of the project exacerbated the crisis caused by climate change in the basin. (Andrés)

However, Humberto particularly highlighted the role of the San Francisco Glacier (Figures 27a and 27b) in imagining critical approaches to environmental education:

> Well, we usually teach about the impressiveness of the glacier at a low altitude, how the glacier was formed, and the importance of the water cycle. We also reflect on why the water cycle is essential, along with teachers. The glacier is a fundamental part of everything, serving as the base for the commune of San José de Maipo and meeting the water needs of all of Santiago. We intertwined all this information so that visitors and children can understand where the river originated, the significance of its tributaries,

> the importance of water to the community, and why it was crucial to take care of this precious resource.

A glacier is a body of ice originating on land through the recrystallisation of snow or other forms of solid precipitation, showing evidence of past and present flow (Meier, 1964). These ice masses are semifluid, with the largest glaciers functioning like conveyor belts: winter snow accumulates in specific areas, transforms into ice, and gradually flows down through outlet glaciers into valleys, where it eventually melts. For a glacier to remain healthy, it must maintain equilibrium by collecting at least as much snow as it loses through melting, ensuring its intake matches or exceeds its output (Magnason, 2020). Understanding Earth's surface and the global environment is impossible without comprehending glaciers. Recently, scientific attention has focused on global environmental issues, particularly climate change and sea-level rise. Glaciers, being key components of both past and future environmental change, are now recognised as central to understanding and modelling the global environment. Therefore, detailed knowledge of glacier characteristics and behaviour is essential (Knight, 1999).

However, as "a fundamental part of everything" is how Humberto portrays the glacier in the interview. For him, the glacier represents not just nature, but also brings possibilities and hope to imagine fairer conditions for living for humans and non-human entities. In this thesis I understand glaciers as more-than-human entities because for me glaciers are not just as physical masses of ice, but as dynamic, interconnected components of larger ecological, cultural, and social systems. Reflections about the meaning of glaciers can be relevant for conscientisation in scientific and environmental education and to reflect the spiritual significance of glaciers in an age of climate change.

For instance, Allison (2015) describes how glaciers as more-than-human entities are often considered sacred, serving as the abodes or embodiments of deities by diverse indigenous groups. For instance, African tribes at the base of Kilimanjaro see the mountain's snow and ice cap as a 'house of god' to be revered from afar. The Ecuadorian mountain Cotacachi is believed to show anger and disappointment over inappropriate behavior and social conflict. In Himalayan Bhutan, high peaks are regarded as the dwelling places of gods, and recreational mountain climbing is prohibited. Similarly, in the Peruvian Andes, local Quechua prophecy warns that the world will end when the snow vanishes from Apu Ausangate, a sacred mountain. The Quechua living near the declining glacier on Mt Ausangate believe that the glacier's disappearance is associated with the departure of the mountain god. In Quechua belief, Mount Ausangate is worshipped as a powerful Apu, god of the landscape, who is a manifestation of Pachamama or Mother Earth. Additionally, people living near the Mingyong Glacier on Mount Khawa Karpo in the Meili Snow Mountains of Yunnan, China, consider their existence and well-being to be intertwined with the glacier's continued existence.

Therefore, physical changes in the Andes landscapes, such as the loss of glaciers, can carry moral and spiritual significance for many indigenous communities, impacting more than just water resources and livelihoods. These changes can disrupt the social and moral fabric of societies, similar to the profound dislocation experienced by, for instance, Native Americans, indigenous groups in the Andes, and Australian Aboriginal peoples following colonisation. Allison (2015) points out that climate change can lead to 'invisible losses' for local and indigenous communities – cultural losses that are traumatic yet often unrecognised. These include losses in culture, identity, belief systems, self-determination, health, and emotional well-being, and also have indirect economic impacts.

It is worth mentioning that Chile lacks specific regulations concerning glaciers. As a result, they are subject to general or sectoral laws[5] that regulate other matters and only tangentially refer to glaciers, offering minimal levels of protection with limited citizen participation and cumbersome regulatory processes that are difficult to implement in practice. Notably, neither the Water Code nor the Mining Code make any reference to glaciers; both were enacted during Pinochet's dictatorship in parallel with the introduction of the neoliberal economic model and have not been significantly modified by subsequent democratic governments, which have maintained this model. Currently, a bill for the protection of glaciers is under consideration, but it has faced strong opposition from the 'productive' sector, particularly from the state and private mining industries.

[5] Laws that exist only in areas where the legislative body has found a particular need.

Figure 28a and Figure 28b. Glaciar San Francisco. (Source: Blacklights)

Both park rangers used dramatic language about the changes they have experienced in their everyday lives over the last decade and the impact of the project on flora, fauna and local glaciers in the Andes mountains:

> The consequences [of Alto Maipo] are also affecting the local wildlife. Species are migrating away from their usual habitats due to the lack of food caused by the changes in the environment. Additionally, the direct pollution of rivers, noise pollution, and the rise in water temperatures due to the altered water flow are concerning issues. The project seems to be releasing heavy minerals and materials into the rivers, further aggravating the situation. Moreover, atmospheric impacts are being observed. The large number of vehicles and trucks moving in the area contributes to the dispersion of dirt and dust particles. These particles adhere to the glaciers, causing them to warm up and accelerate the melting process. (Andrés)

> All around this area, you look, for example, ahead, you keep looking at the mountains, you keep seeing all of this, you keep seeing the glacier in the background next to San José volcano, and one sees it day by day and I say, ten years ago, the glacier was much broader, much larger. I can estimate that the glaciers in the central area melt up to six meters per year. (Humberto)

Objective scientific observations agree with Humberto' estimation. Glacial retreat has reduced river flows to historically low levels. The global phenomenon of ice mass loss, as a consequence of climate change, has been particularly pronounced in Chile due to the combined effects of a prolonged mega-drought and air pollution over the past decade, with studies indicating significant retreats in the central region's most notable glaciers (Cereceda-Balic et al., 2022). However, this global phenomenon is also seen to be accelerated by the Alto Maipo hydroelectric project, which poses a serious threat to the Maipo Basin and the area's glaciers.

To understand the existence of this 'monster' that lies dormant in the Andes from a legal perspective, it is essential to question the methods and regulations used to measure the environmental impact of a project of this magnitude in Chile. According to Humberto and Andrés, these impacts are often invisible, slow, or silent to humans. Humberto particularly mentioned something about the limitations of our perception:

> The sounds produced by the tunnel hydraulic fracturing processes of Alto Maipo project can affect many insects or birds without us realising it. Many of the instruments

> used to measure these impacts are insufficient to detect changes in the environment that are often imperceptible or not considered relevant in environmental impact reports. Another example is the temperature changes that occurred when drilling the ground. We witnessed many birds migrating due to changes in the local environment and ecosystems. This could be explained by changes in the soil and underground layers which can affect the birds' nesting stages. (Humberto)

Environmental regulation is stipulated in Article 19 of the Chilean Constitution (which remains in force today), drafted in 1980 during Pinochet's civic-military dictatorship. This regulation proposes the protection of environment as a fundamental human right:

> It is the role of the state to guarantee the right to live in an environment free from contamination. It is the duty of the State to ensure that this right is not affected and to oversee the preservation of nature.
>
> The law may establish specific restrictions on the exercise of certain rights or freedoms to protect the environment, especially when the right to live in an environment free from contamination is affected by an illegal act or omission attributable to an authority or individual. (Art. 19.8. Protection of the environment and nature, 1980 Chilean Constitution)

However, Galdamez (2017) discusses how there are different ways or conceptualisations of how to think about the concept of nature in different constitutions around the world: nature as *näive* reality, as moral imperative, as Eden, as self-conscious artifact, as cultural artifact, as virtual reality, as commodity, as demonic-other, or as contested terrain. In this sense, Cronon (1996) argues that the reality of nature is undeniable, but the fact that it escapes our linguistic universe makes it ungraspable and, at the same time, a subject of dispute, conflict and over exploitation. Each of these ways of understanding nature is associated with human-nature relationships in normally asymmetrical definitions of access, control, and use. These definitions open new lines of understanding about how discourses associated with nature are employed to get access to development projects of this magnitude through legal and political arguments that support a certain method of evaluating the environmental impact of a project. In Latin America, numerous cases have exposed corrupt practices surrounding various extractive ventures. Some of these, such as the cases involving Brazilian corporations Petrobras and Odebrecht, have ramifications in several countries. The connections between corruption, lobby and extractivism therefore exist and are varied (Gudynas, 2019).

In the recent constitution drafted in Chile in 2020, there were concrete opportunities to change and improve the definition of nature, recognising fundamental rights associated with the environment, even acknowledging nature as a subject of fundamental rights. The draft Constitutional Convention's text stated:

> 1. Nature has rights. The State and society have the duty to protect and respect them; 2- The State must adopt an ecologically responsible administration and promote environmental and science education through permanent training and learning processes. (Article 127.1, Convención Constitucional, 2022)

The new proposal's explicit commitment to promoting environmental and science education through ongoing training and learning processes was particularly inspiring. For me, it represented a call for hope. Had it passed, Chile would have joined other Latin American nations and countries like New Zealand in expanding rights by recognising nature as a legal rights holder, with both society and the State responsible for protecting and respecting these rights. However, this vision was not realised, as the 2022 Chilean constitution was ultimately rejected. The constitution failed, primarily due to concerns about its ambitious scope, perceived divisiveness, and complexity. While it sought to address social inequalities, environmental rights, and Indigenous autonomy, critics saw it as too radical, fearing it could lead to instability or excessive government intervention. As a result, many voters viewed it as a step too far from the current framework, leading to its rejection in the national referendum.

The effects of river and soil pollution, despite being imperceptible in the short term, create significant environmental impacts. The processes to mitigate these damages are very complex, slow, and costly. Soil degradation through the contamination of groundwater and surface water has directly affected natural heritage, causing significant imbalances in biodiversity. Similarly, the environmental impact of extractive processes not only affects the natural environment but also has repercussions on the socio-cultural environment through the destruction of traditional cultural resources, such as regional practices or ancestral practices related to the use of agricultural soil and/or livestock activity.

However, as shared in the next excerpt, there are some tensions between public science and environmental educators and, unfortunately, when it comes to addressing more political or critical issues, the voices of park rangers are often silenced by institutional constraints:

> Well, Gonzalo, I could talk about Alto Maipo a lot, but, probably, we are conditioned. What I think as a park ranger cannot unfortunately be said publicly; it is complex. We

> cannot talk about a project for which we are prohibited from issuing judgments because, of course, technically, we have the expertise, but here the one who has the voice are those who participated in evaluating the project. (Andrés)

Consequently, the park rangers' agency is diminished, leaving the task of engaging with these political issues primarily to teachers or those fortunate enough to possess deeper knowledge about the happenings beneath the glacier and specifically about Alto Maipo. As noted by them, "the consequences are also affecting the local wildlife" and the presence of Alto Maipo brings questions about "the importance of water to the community". In that way, in their discourses, I can see how the glacier has become a transdisciplinary actor to think with. It brings and facilitates discussions not just about science, but also about basic human rights such as access to water, and how knowledge is distributed, and voices are heard. Moreover, it fosters discussions about what is essential for living, either a Natural Monument, or an industry, and the need to bring new relationships through science that are not exploitative and extractivist for the sake of development for a few at the expense of others.

In Kimmerer's (2012) words, the environmental crises we are suffering today are also part of "the degradation of our relationship with the living world and the extinction of an ethical responsibility for the land which sustains us" (p. 317). Expanding what counts as science education to think with and within nature, as the park rangers do, is a way of developing critical scientific and environmental literacies that can help us, researchers, educators, and students, develop conscientisation of what is of value, what is essential, and whose knowledges we bring to learn with when learning science in different settings.

However, there are actors, such as the park rangers and the San Francisco Glacier itself, whose voices have been silenced. When a voice is silenced, that silence also carries out discourses of science (Torres-Olave & Dillon, 2022). What is untold can be presented as of non-value or not essential for the experience within the park and what the park in itself represents for the local community, not only today but at larger scales. As noted by George and Wiebe (2020), learning with more-than human entities and thinking about time with other rhythms and scales can present challenges to Western modern science, particularly shifting "possessive, property-driven forms of citizenship and instead centre reciprocal relations of abundance and care with and among human and more-than-human lifeworlds" (p. 519). Learning through the relationship between the park rangers and the glacier has meant learning stories that travel across generations. Stories that can be of value to science and other disciplines. Stories that can advance caring, ethical, and conscious relationships through science. Even though this process of developing conscientisation is neither simple nor solely the responsibility of schoolteachers, there are ways of distributing such ethical tasks.

To promote critical scientific and environmental literacies, we must also demand ecological responsibility from various individuals, which necessitates concrete actions. For instance, as the park rangers suggested, the park can serve as a scientific laboratory where students and others can cultivate their imagination. This type of imagination fosters relationships that are ecologically and ethically responsible, centring learning experiences not only in students but also within the broader world we inhabit. Such engagement is vital not only for school curricula but also for higher education, as demonstrated by land-based pedagogies in science teacher education and other science-related fields (Hage et al., 2022). Furthermore, if we utilise outdoor education beyond mere visits, the knowledge of park rangers can contribute to an ecology of knowledges essential for science education, thereby challenging traditional epistemic hierarchies about who holds scientific knowledge (Hecht & Nelson, 2022). In this sense, we can promote critical and collective literacies.

As argued by McEntee et al. (2023), these stories also show that park rangers "have a nuanced knowledge of place" (p. 127). The movements, changes, losses and impacts of the park highlighted by them require a rich understanding of the relationships, the geographies, and the diversity of habitats of the park. Through their knowledge of affective, structural, and content-related dimensions, they advance notions of science and ecological ethics essential for conscientisation processes. Park rangers' stories also highlighted the centrality of learning about specific places and the value of oral stories of those who have been in the space for, in the case of the park rangers, over more than two decades. When they said, "comparing the present to a decade ago, the glacier was much wider and larger", they brought with them other stories and dimensions of science to which we usually do not pay the necessary attention: non-linear, more broad temporal dynamics and rhythms. As such, park rangers play a crucial role in introducing students and visitors in general to different temporal and spatial scales. Similarly to Bonelli and Dorador (2021), park rangers are thinking not only of humans but also of non- and more-than-human time scales.

One of humanity's significant challenges today is the temporal gap between our imagination and socio-cultural-environmental conditions. These temporal disparities have political implications, particularly evident in how we value glaciers, shaping their significance for only a few. Thinking within extractivist and immediatist temporal scales influences our beliefs and needs. As Facer (2023) notes, we must "cultivate such a temporal imagination as a resource for possibility thinking, starting from the premise that temporal imagination, like any other imaginative activity, is supported by social and cultural resources that provide tools, images, and concepts to scaffold and mediate our understanding of the world" (p. 62).

Park rangers' stories of and with the glacier can help to scaffold those ideas of interconnection and interdependence, reflecting on the impacts that Alto Maipo has on the glacier and on the whole hydrological system and veins of Santiago. In their stories, park rangers also share other starting points. It is not just the glacier and what it is today, but also what it was, and also what it could be in the future with its influences on life more broadly. Those stories of science are vital because they problematise when time 'starts' to be counted, which, as a consequence, impacts our ways of thinking and the limits of our imagination. If we continue thinking at the scales we inhabit, or in the short-term, our process of conscientisation will be hindered because moving towards fairer worlds is not just about us: it also needs to include the past and futures to which we do not belong. Those temporal scales strongly influence how we live today. For example, in the case of Chile, neoliberal logic has shaped neo-extractivist practices, and notions of techno-scientific futures as linear with infinite accumulation and growth (Svampa, 2019; Villavicencio, 2021). Therefore, it is vital to recognise that a climate crisis and the impact of global warming are already exerting considerable stress on the Andean ecosystems, and any additional disturbances from large-scale projects like Alto Maipo may only worsen the situation. Collective, critical, and relational responsibility from critical science and environmental educators is vital to contesting this monster in the park.

6.4 After the visit

At the conclusion of our visit to the park, I took the initiative to reach out to all the participants involved in the project via WhatsApp. My aim was to gather their immediate reflections and thoughts following their experiences in 'El Morado'. This feedback was crucial as it helps to understand the impact of the visit on each individual and gather insights about how outdoor education can promote critical approaches for science and environmental education, helping answer my research question. Andrea was the first to respond to my request. Her prompt reply was not only indicative of her engagement with the project but also set the tone for the kind of thoughtful and detailed feedback:

> First of all, I feel grateful for being part of this project. I want to thank you, Humberto, and Andrés for the time you gave us and for receiving us. I had never been to the park

> before, I did not know that ‘El Morado’ exists. It was an experience I believe I will never forget. Now I am curious to keep visiting other parks and continue learning about flora and fauna in Santiago. I think this way I can raise more ‘awareness’ about everything. I believe all the learning today is thanks to the role of the guide [Humberto]. I think the role of park rangers is key in planning educational field trips. Humberto knows a lot about the local flora and fauna, and I think he is a great ally in linking the curriculum with the visit. I feel very happy. I think I agree with Andrés: “one day in the park is enough to have seven days of happiness”. However, I do feel dizzy. Perhaps it’s because of the altitude, I feel like I am *walking on eggshells*. But I feel amazed looking at the photos and remembering the experience.

Angelica disclosed that she only had a chance to really think about her park visit a day later. For the upcoming visits, she recommended some improvements that would spice up the adventure and the field trip, a suggestion that would connect with previous community dialogues:

> It would be interesting to interview families living in the area and gather additional testimonies from local people to address the emotional dimension. Conversations with families could cover topics such as climate change in the area, which might promote empathy among the students. For example, students could interview grandmothers to hear the feelings behind these testimonies. From these stories, students could develop a reflection to be related to the educational field trip.
>
> Regarding my perceptions about this field trip, I found it super cool, and I think the participation of Tomas and Humberto was extremely relevant. I believe that to undertake a field trip of this nature, it is necessary to have some basic knowledge (even if just a little) to understand the ecosystem and the importance of the natural monument. Throughout the journey, despite the fatigue, I felt an incredible peace mixed with a bit of nostalgia. Personally, having been born and spent part of my childhood in the countryside, I felt like a fish in water! At the same time, I felt very, very small. The majesty of the place is incredible, and how it is constantly changing without us noticing (and also without being aware of how our actions accelerate such changes). On the other hand, I was struck by the fact that there is a certain indifference from people who were born and live there regarding the effects that activities such as Alto Maipo have on the ecosystem. One tends to think that their ecological education would be greater than

> that of someone from the capital since they are constantly in contact with nature. I also realised that this lack of ecological education has been present for a long time.
>
> All of this leaves me with many doubts and questions: How can we transform this experience into something meaningful for students who are completely distant and indifferent to the topic? How can we transfer and instil this sense of admiration and protection for monuments, reserves, and national parks? Lastly, I would love to learn much more about public policies aimed at protecting and conserving these areas and be able to address them in some way in an ecosystem class with the objective of working on and promoting critical thinking in students regarding these issues.

Paulina also mentioned some deep reflections highlighting the role of park rangers and in-service teachers:

> Yesterday was a beautiful, rejuvenating, and energising day. Regarding the planning, we could have started earlier; everything else was great, the scenery was wonderful, so that's the only thing I would improve. Yesterday, I learnt a lot from talking with the park ranger and with Clara about pedagogy and outdoor education and the beautiful landscape we were seeing. I definitely see myself taking a trip like this with my students, as I feel that if one does not see the wonders that could be lost to exploitative projects, one does not value them. I feel that one must experience it to explain and defend it; otherwise, it all feels very distant. I think the students need to feel the immensity and beauty that we have in Santiago to appreciate and protect it.

These narratives show the major influence of outdoor education on nurturing awareness of the environment and thinking critically about nature. All pre-service teachers expressed gratitude for the opportunity to experience 'El Morado' and emphasised the importance of guided educational field trips in enhancing a deep understanding of the ecosystem. Humberto was in some way instrumental in connecting theory with practice, hence helping all the group to get deeper insights into natural history, ecological concepts and the importance of conservation. The emotional connection and sense of wonder experienced by the participants underscore the value of direct interaction with nature, which often cannot be replicated in a traditional classroom setting.

Angelica's suggestion to include prior conversations with the local community further enriches this educational approach by integrating socio-cultural perspectives and personal testimonies. Such interactions can deepen students' empathy and awareness of environmental issues, including climate change, by providing a human and place-based context to scientific data. This holistic approach not only educates but can also inspire a sense of responsibility and activism among students. This idea of including local narratives is a key component of critical scientific and environmental literacies considering that students can better appreciate the interconnectedness of natural and human systems and the urgent need for sustainable practices as collective endeavours. Thus, outdoor education effectively fosters critical approaches for conscientisation and encourages students to become active participants in environmental stewardship.

6.5 Concluding remarks

The promotion of critical scientific and environmental literacies through outdoor education can be extensive, as demonstrated by the opportunities and insights gathered from the collaborative research project and the activities at the field trip to the 'El Morado' national park in Chile. This critical approach has the potential to integrate experiential learning with critical analysis of historical and material reality, encouraging students to engage deeply with both scientific concepts and socio-environmental issues. There are several key points based on the content from Chapter 6 to answer explicitly my third research question:

1. 'El Morado' provides a rich, hands-on learning environment where visitors can directly observe natural phenomena and engage with the environment in a way that is both sensory and immersive. This connection with nature promotes interest and a potential deeper understanding of ecological concepts and the importance of biodiversity conservation. For instance, as one of park rangers noted, visiting the park offers a new way to understand nature in an interconnected way. Visitors and students visiting the park could understand where the river originated, the significance of Rio Maipo tributaries and veins, the importance of water to their community, and why it is crucial to take care of this precious resource. The interactions with park rangers and the direct observation of the landscape help in cultivating an emotional connection with nature, fostering a sense of responsibility and stewardship which is also part of critical approaches.
2. Outdoor education offers a contextual understanding of environmental issues by linking the observation of natural phenomena to broader environmental and socio-political issues; students are encouraged to think critically about sustainability, climate change, and the impact of human actions on the environment. The case of the Alto Maipo project,

for instance, illustrates the complexities of environmental conflicts and the need for a critical approach to understanding some conflicts which can be also be analysed as socio-scientific issues. This contextual learning helps students see the relevance of scientific concepts to ‘real-world’ challenges.

3. The park serves as a ‘small science laboratory’ where various disciplines can intersect. Students can explore topics ranging from geology, hydrology, and biology to social sciences and ethics. This interdisciplinary approach not only enriches students’ scientific knowledge but also helps them understand the interconnectedness of natural and human systems. The visit to the park with different participants, with different backgrounds and expertise, underscores the importance of considering multiple perspectives and disciplines when addressing environmental issues.
4. The fieldtrip carried out at ‘El Morado’ might encourage visitors and students to ask critical questions and engage in ethical reasoning. For instance, if the park rangers are open to discussing the relevance of the glacier, rivers and hydrological system of the Maipo Basin, there are many opportunities to examine the environmental and social impacts of projects like Alto Maipo. Outdoor education brings opportunities to assess the implications of human activities on the environment and consider the ethical dimensions of sustainability and conservation. This critical thinking is essential for developing informed and conscientious citizens who are prepared to tackle environmental challenges.
5. Park rangers and environmental activists play a crucial role in outdoor education, serving as non-formal educators who provide valuable insights and facilitate learning. Their stories and experiences help bridge the gap between scientific knowledge and practical, territorial applications. This highlights the importance of community involvement and the inclusion of diverse voices in environmental and science education.
6. Outdoor education at ‘El Morado’ also emphasises the emotional and spiritual aspects of learning. The natural beauty and majesty of the landscape, particularly the San Francisco Glacier, inspire a sense of awe and connection to the environment, which is often missing in traditional classroom settings. This emotional engagement is crucial for fostering a lasting commitment to environmental stewardship and sustainability as part of critical scientific and environmental literacies.

To sum up, outdoor education at ‘El Morado’ national park demonstrates the potential to promote critical scientific and environmental literacies through a combination of experiential learning, contextual understanding, interdisciplinary approaches, and ethical reasoning. By engaging with the natural world and examining the socio-environmental conflict Alto Maipo, students can develop a holistic and informed perspective that is essential for addressing the complex environmental challenges of our time.

6.6 After some years

Since the first visit to the park in 2020, several years have passed, and many stories can be told about what happened after the visit to 'El Morado'. I consider this section relevant since it is an essential part of my epistemology described in Chapter 4. Moreover, CPR aims to be a long-term relationship which I have strived to maintain over the past four. Although, I have unfortunately lost contact with Angelica and Paulina, I am in touch with the others who participated in the fieldtrip.

Ursula continues to work as a teacher educator, particularly in the master's and doctoral programmes at her university. Ursula has become a fundamental ally and academic partner in promoting critical approaches in science education. We have remained in contact, leading and collaborating on various projects. With Ursula and other colleagues, I have published two Springer book chapters. In the first one, we invited colleagues and researchers to reflect on how to integrate critical theories into environmental and science education, particularly in outdoor education. In the second one, we networked with other researchers from Latin America (Brazil, Mexico, Colombia, and Peru) with whom we have collaboratively debated the relevance of contextualising science and environmental teaching to the local realities of Latin America. Additionally, Ursula and I have supervised two master's theses related to scientific literacy, zones of sacrifice and activism in science and environmental education. One of them was published in *Cultural Studies of Science Education*, and the second is soon to be included in the new STEPWISE book edited by Dr. Larry Bencze. These works can be found in the reference list at the beginning of this thesis.

I continue to work with Antonia and Andrea. Thanks to the support of Ursula and other researchers, I was invited to lead a collaborative research project to design a new textbook for the Chilean Ministry of Education for a new curriculum subject titled 'Science for Citizenship'. This book was a collective creation involving more than 15 school science teachers. For the first time in Chile a textbook was created collaboratively and including teachers' voices. In this book, Antonia and Andrea played a crucial role, leading and creating various modules and didactic sequences, which built on the previous collaborative research work we had done. Some of the infographics and activities they created are specifically related to promoting critical approaches to environmental and sustainability issues. Today, both are working in public educational institutions in Chile. We remain in contact to share experiences.

Clara and María continue to work as in-service science teachers. In 2022, they invited me to give a talk at their school about environmental education and climate change. Since then, we have not had much contact, due to the busyness of their work and family lives, but there is still much affection between us. Rubén and I have a number of meetings about thesis supervision with one of his students from the University.

Andrés and Humberto continue to work in the park. They play a very important role in continuing to educate the more than 15,000 visitors the park receives each year. Every time I have the opportunity to go to Chile, we reconnect. This year, we started to discuss the findings from my doctoral work. Our plan for the near future is to coordinate the design of signage for the park and produce educational materials to be used by the teachers who visit 'El Morado'.

Regarding Alto Maipo, Clarin (2024) has recently summarised the situation by saying that, currently, the project is on hold. In February 2023, the construction company Strabag took Alto Maipo to arbitration at the International Chamber of Commerce. This was due to the withdrawal of funds in a letter of credit to, according to the Austrian company in charge of the construction of the Chilean project, 'cover its liquidity shortfall'. In mid-November, after poor results in the US courts, the company intensified their offensive and approached the highest court in New York to request a precautionary measure. The company claims that, for the second time, Alto Maipo is 'on the brink of insolvency and bankruptcy' and that if the Supreme Court does not intervene, they could lose millions of dollars. AES Andes' subsidiary has a different version of events: they point to their counterpart as responsible for collapses in their tunnels and declare that they have the right to access these funds because the established deadlines were not met. Additionally, company sources firmly deny a possible bankruptcy.

Gone are the banners, mobilisations, and public criticism of Alto Maipo. Today, the main concern of the hydroelectric company is with one of the contractors behind the project, which is accused of being responsible for various collapses that threaten the start-up of Chile's most important 'renewable energy' plant. Their counterpart, however, has its own version of the events. Meanwhile, no one will remedy the acceleration of the melting of the glaciers bordering the Cajón del Maipo due to the construction work on the intakes and the dust, no one will remedy the environmental wear of the intakes and the tunnel, and no one will remedy the increase in drought due to the water theft by Central Alto Maipo from this basin over the last few years.

Chapter 7. Discussion and general conclusions

7.1 Answers to research questions

7.1.1 Answer to research question 1

To answer the first research question ‘How have critical scientific and environmental literacies been understood in the last three decades, and what are the opportunities for a potential convergence between these concepts?’, this thesis first conducted a systematic review of the concept of scientific literacy and its potential integration with environmental literacies from critical perspectives. The results show that over the last 30 years, the development of both concepts has been framed and influenced by political, cultural, historical, economic, and ethical dimensions. The conceptualisation of what is understood by ‘literacy’ particularly, as applied in science education, remains complex. However, it is clear that critical approaches to literacy have been internationally understood by various authors as a socio-political practice involving a collective process. In this sense, educating the public scientifically and environmentally is a collective endeavour that should focus on transformation and emancipation.

In the same vein, this thesis demonstrates that science and environmental education must collaboratively address global and complex hazards such as biodiversity loss, droughts, and the climate crisis, viewing them as intertwined polycrises to effectively tackle them as socio-environmental and political conflicts (Dillon, 2016). This integration is needed because fusing these disciplines is essential for developing a comprehensive understanding and creating effective strategies to adapt and mitigate these present and future challenges. Navigating and interrogating the notions of literacies from critical perspectives may provide options to understand what (in)justices are perpetrated in the name of these slogans. As shown in this thesis (see Chapter 3), some possibilities to address the integration of both concepts emerge from outdoor education and from connecting science and environmental education with climate change education. Expertise in outdoor education should be an essential component of teacher science education programmes, and climate change education should be mandatory and explicitly addressed in the general curriculum or at least in the science curriculum. As seen in Salinas et al. (2022), there are two potential options for including this new discipline. One option is to add more content related to climate change education through a comprehensive theory of curriculum integration, considering the convergence of four aspects: (i) integration of experiences; (ii) social integration; (iii) knowledge integration; and (iv) integration as curriculum design (Beane, 1997). The second option is to include climate change as a new subject in the general curriculum. However, in both options a critical vision of scientific and environmental literacy should be considered.

Scientific literacy from a critical perspective implies transcending traditional or classic views of the concept, such as *Vision I* and *Vision II*. The findings from the first part of this thesis (see Chapters 2 and 3) demonstrated that discussing literacy from a non-hegemonic view opens possibilities for considering literacy as an explicitly human-constructed activity. This perspective provides concrete opportunities to understand and affirm that science education is a socio-cultural, human, political, ethical, community-based, and constantly evolving activity. As shown in Chapter 3, various authors argue that critical approaches to scientific literacy are essential for addressing current and future challenges, such as the global climate crisis. Given the complexity of future scenarios and the multiple crises we already face as humanity, critical approaches to science and environmental literacies offer concrete opportunities to promote a view of education focused on climate action (see Chapter 1). However, action and activisms are also complex concepts that need to consider the material and historical challenges and realities of contexts, especially in Latin America and in other contexts with shared complexities. To advance these challenges, it is imperative to consider the territory and the specific educational realities of each particular context. Therefore, discussing critical scientific and environmental literacy means rethinking the role of science as a discipline embedded in a broad network of material and political structures.

Since the early 1990s, the understanding of the concept of literacy has evolved beyond the mere ability to read and write or possess knowledge or proficiency in specific fields. It has reached a critical threshold intricately intertwined with science, politics, and the role of the government (Mayor, 1992). Many international organisations, such as UNESCO and the UN, have developed goals related to scientific literacy due to the increasingly rapid and diverse relationship between industry and scientific developments. During the 1990s, metaphors for critical literacies emerged: literacy as adaptation, literacy as a state of grace, and literacy as power. However, while literacy in science education served as a metaphor, it also became a slogan and rallying cry for science curriculum reforms (Bailey et al., 1998). Critical literacies were thus understood as opportunities to question the injustices that occur when a powerful group of people or a hegemonic vision of scientific and environmental literacies perpetuates narrow views of literacy. By defining a set of criteria for what constitutes a scientifically or environmentally literate citizen, these groups can reinforce their own position and authority, thereby excluding other ways of understanding literacy in specific contexts, territories, and languages.

In the first decade of the 21st century, the understanding of scientific and environmental literacies based on new approaches was consolidated. New and more didactic approaches helped in the development of critical literacies in science that consider social and environmental issues. This marked the beginning of the integration of science and environmental education from critical perspectives in a more explicit way. Donnelly (2005) discusses how this decade saw a global trend in reforming science curricula to incorporate a range of different literacies, including social, political, health, environmental, and emotional ones. The last one is particularly relevant for mobilising emotional relationships with nature (Pascuas Rengifo et al., 2020). However, during the same decade, hegemonic views of scientific literacy were globalised, leading countries to mimic these standards to achieve a 'satisfactory' level of literacy among citizens. This implementation was facilitated through performance-based global standardised tests such as PISA and TIMSS (Chinn, 2007).

Paradoxically, this situation led to the emergence and consolidation of critical approaches as a confrontation between hegemonic and marginalised cultures, which sought to recognise excluded voices and local approaches. During this period, the understanding of scientific literacy began to include a pluralistic approach that also recognised indigenous knowledge systems. Thus, a decolonial perspective paved the way for critical scientific and environmental literacies. Traditional Western approaches to the human-nature connection typically seek knowledge for economic gain and power over nature (Ogawa, 2004). In contrast, indigenous knowledge systems are crucial for critical approaches in science and environmental literacies, as they prioritise harmony, interconnection, and interdependence with nature. In this sense:

> Opening ourselves to the possibility of plural ontological realities can reveal differences in how phenomena and societal issues are perceived and how they might be more justly acted upon, especially in relation to the different axiological commitments they bring to bear in supporting students to relate to the world. (Running-Hawk Johnson et al., 2023, p. 584)

By embracing these diverse perspectives, educational practices can become more inclusive and equitable, supporting students in developing a more profound connection to and understanding of the world around them. For instance, according to Reiss (1993), we should not assume that all scientific thinking processes within a particular society operate within the same paradigm. Differences in important characteristics such as gender, religious beliefs (or cosmovision in the case of indigenous people), ethnicity, class, age, and disability can lead to varied scientific understandings and conceptions of the world among individuals (Hodson, 2011).

In terms of environmental literacies, Potter (2009) suggests that critical environmental literacies are fundamental for addressing the economic, social, and ecological problems that profoundly impact us as present and future inhabitants of this planet. Traditional ecological literacy approaches are often superficial and disconnected from socio-scientific and socio-environmental conflicts. Santos (2006) and Marks et al. (2008) advocate more human and pluralistic approaches to environmental literacies, promoting socio-critical and problem-oriented ideas. This thesis shows that there are real opportunities to include socio-environmental conflicts (such as Alto Maipo) and the potential use of different digital platforms (e.g., EJAtlas and INDH map) to gather information and address broader dimensions of science and environmental education.

During the last decade, the understanding of scientific and environmental literacies in Latin America has been deeply influenced by the work of Paulo Freire (Marcelino & Tormöhlen, 2024). Yet, there is a need to consolidate and expand South-South relationships, allowing groups in Latin America, Asia and Africa to share their experiences in Freirean science education and reflect on their shared history of oppression to construct liberating educational programmes. However, as discussed similarly by Marcelino and Tormöhlen (2024), some limitations of the systematic literature review in this thesis are related to the representation and publication of academic studies. Latin American journals (and perhaps Asian and African ones) are not fully represented in the Web of Science or other databases focused on metrics studies of information. This limitation hinders access and bibliometric analysis of research from these regions. While Redalyc and SciELO provide an important service in disseminating Latin American research worldwide, their data systematisation and exportation tools need improvement.

The results of the systematic literature review in this thesis offer diverse perspectives for imagining approaches from the Global South. Regarding the importance of critical scientific and environmental literacy for Latin America, it is relevant to note that a hegemonic vision of scientific literacies has prevailed in the region from a neoliberal rational perspective, primarily around *Vision I* and *Vision II* (Guerrero & Torres-Olave, 2022; Salinas et al., 2023).

This vision has become part of the social structure, permeating public policy, schools, cultures, and individual and collective practices, where values from an anthropocentric approach dominate the discussion and are largely the cause of the social and environmental challenges facing the region, including Chile.

Another important perspective in critical scientific and environmental literacies is the humanistic approach, which understands science education as inherently political. Critical approaches and the ensemble of critical science and environmental literacies align perfectly well with the socio-political turn in science education discussed by Tolbert and Bazzul (2017):

> A socio-political turn foregrounds a political horizon that is gradually extending and evolving to include a growing number of social struggles. These include addressing racial inequality, issues of sex/gender and sexuality, economic justice, and environmental movements that value non-human and even abiotic entities as worthy of equal consideration. (p. 324)

A socio-political turn in science education seeks to redraw the boundaries of the social world, challenging the forced dichotomy between natural and social realms and educational communities, all in the name of equality (Tolbert & Bazzul, 2017). A socio-political turn both in science and environmental education is not only imminent but necessary to address the polycrises of the twenty-first century. Moreover, critical approaches about science environmental literacies have the potential to be aligned with ecofeminist theories – understanding the interconnections between the exploitation of nature and the oppression of women – thus growing awareness of environmental issues and the feminist critique of patriarchy.

Additionally, in the last decade, there has been a growing concern for ecological issues, climate change, and political matters. Political literacies have become a key ally in addressing environmental issues, influencing the conceptualisation of literacies in both science and environmental education. These new understandings are being translated into revised and new definitions of literacies, contributing to the development of more qualified scientifically and environmentally ‘literate’ citizens. For instance, Latin American scholars like Sánches (2015) have highlighted critical dimensions for raising awareness of environmental literacies based on interdependence, the cyclical nature of ecological processes, and the cyclical exchanges of energy and resources, establishing a link between non-human and human entities. During this period, we can see significant theoretical and empirical opportunities for the integration of scientific and environmental literacies. Critical approaches to ecological literacies might be introduced or infused into science education curricula, focusing on understanding the interdependence between human and non-human entities in their specific ecological contexts. This approach is essential for rethinking the concept of sustainability from non-hegemonic perspectives.

As seen in this thesis, outdoor education presents real opportunities for integrating science and environmental literacies by providing ‘real-world’ and complex scenarios that facilitate and enhance conscientisation processes (see Chapter 3). Latour’s concept of ‘unfinished science’ applied in outdoor education shows opportunities to tackle controversies and explore natural phenomena in depth. Outdoor education helps students understand and reflect on how scientific knowledge is produced through networks of actors, including scientists, instruments, institutions, and even non-human entities. Scientific advancements often arise from disputes and discussions among scientists, rather than from straightforward accumulations of facts. Unfinished science encourages greater public engagement and participation in scientific discourse. Thus, enhancing our understanding of scientific knowledge as a dynamic, contested, and socially embedded process. In this sense as highlighted by Starratt (2002), ‘the community is the curriculum’.

The concept of environmental literacy finds a niche in science education (Wals et al., 2014) and, based on the results of this thesis, there are many opportunities to articulate this concept with scientific literacy and other literacies, such as ecological, political, emotional, climate change, sustainability, and biodiversity literacies, especially today in times of ecological crises and natural disasters. However, the complexity of each of these concepts shows that trying to reduce the complexity of traditional approaches can lose the main intention when articulated with the concept of scientific literacy. Therefore, as a conclusion of this first part of this doctoral thesis, it can be said that if we intend to articulate the concept of environmental literacy with that of scientific literacy, the first step would be to consider the critical perspectives that have been addressed in recent times. This process involves: considering a biocentric perspective, recognising the interconnection and interdependence between humans and nature, and not the false dichotomy from which much of the knowledge in science has been built; a holistic view of socio-ecological systems; and finally, the integration of diverse views and worldviews on how the world is perceived, categorised, and even protected by different cultures and indigenous knowledge systems and ontologies.

7.1.2 Answer to research question 2

Regarding the second research question of this project 'How does collaboration enhance the expertise of pre-service teachers in outdoor education?', the empirical research conducted for this PhD thesis reveals critical insights into the challenges and opportunities associated with enhancing outdoor education expertise among pre-service teachers in Chile. Collaboration enhances the expertise of pre-service teachers in outdoor education by bridging the gap between theoretical knowledge and practical application. Empirical research conducted for this PhD thesis reveals that pre-service teachers often face significant barriers due to limited training and information in outdoor education, leaving them underprepared and isolated when attempting to implement outdoor activities. However, through collaborative and participatory research with experienced educators, such as in-service teachers, science educators and park rangers, pre-service teachers gain access to a range of insights, practical strategies, and interdisciplinary approaches, which collectively build their expertise and confidence.

Park rangers and in-service teachers in this project highlighted the importance of hands-on, sensory engagement in outdoor settings, arguing that learning in natural environments can deepen scientific and environmental awareness. They also advocated an interdisciplinary approach, showing pre-service teachers how to integrate scientific and ecological concepts with real-world issues and historical context. For instance, during focus groups and visit to the park, discussions on the relevance of local ecosystems—such as glaciers—allowed pre-service teachers to see the interdependence of natural processes and human activities, thereby enhancing both environmental awareness and teaching efficacy.

Furthermore, dialogical seminars provided a space for pre-service teachers to engage in reflective discussions, sharing ideas with others from different professional backgrounds. These collaborative sessions underscored the value of experiential learning, interdisciplinary planning, and practical strategies to address administrative and logistical challenges often encountered in outdoor education. By discussing bureaucratic and safety concerns, pre-service teachers gained a clearer understanding of the steps involved in planning and executing outdoor lessons, from legal regulations to health and safety considerations, thus equipping them to handle these tasks more effectively.

Collaborative learning through these seminars also enhanced pre-service teachers' pedagogical skills, as they observed and participated in interdisciplinary discussions that addressed not only technical knowledge but also the emotional and sensory aspects of outdoor education. For example, park rangers demonstrated how to create meaningful educational experiences that leverage the sensory elements of nature – visual, auditory, and olfactory – to engage students fully, fostering a deeper connection to the environment.

In light of these findings, this thesis advocates for systemic changes in teacher education to incorporate more comprehensive training in outdoor education. Such reforms would support pre-service teachers by facilitating partnerships and collaboration with experienced outdoor educators, enhancing their expertise and confidence in delivering effective outdoor education. Overall, this collaborative research approach to training pre-service teachers prepares them to handle complex environmental and educational challenges, making outdoor education a more integral and impactful part of the educational experience.

7.1.3 Answer to research question 3

Regarding the final research question, 'To what extent can a critical scientific and environmental literacy approach be promoted through outdoor education?', this thesis confirms that a critical scientific and environmental literacy approach can be effectively promoted through outdoor science activities, as demonstrated by the empirical research, dialogues and experiences documented at 'El Morado' National Park, which go beyond traditional educational models to foster transformative and action-oriented engagement with scientific and environmental concepts.

The immersive experiences at El Morado National Park illustrate how direct engagement with ecosystems can nurture critical environmental awareness and conscientisation. Particularly, park rangers used the park's geological formations, glaciers, and wildlife to highlight the interconnections within natural systems and our reliance on them. For instance, learning about the glacier's role in Santiago's water supply emphasised the critical importance of these resources, encouraging participants to see environmental stewardship as a responsibility tied to socio-ecological justice. Observing local species and their roles—like carrion birds in decomposition and reptiles in pest control—provided insight into ecosystem stability, demonstrating how these natural processes help sustain agricultural and economic systems without relying on chemical interventions.

In addition, the activist reflections and the network of actors around Alto Maipo, developed collectively, underscore the impact of neoliberal policies on nature, bringing attention to the 'neoliberalisation of nature' where corporate interests and profit-driven agendas lead to the systematic and historical exploitation of ecosystems, often with severe consequences for local communities. Alto Maipo's rapid approval – designated as a "project of national interest" – reveals how regulatory systems can be manipulated, with economic priorities superseding environmental protection. This scenario prompted critical reflection among participants, allowing them to question the role of extractivist policies and explore how such projects affect both ecological systems and social equity. It became clear that promoting critical environmental literacy involves not only understanding scientific and ecological concepts but also critically examining the socio-political forces that shape environmental policies.

My journey as a researcher mirrored this process of conscientisation, deepening my awareness of the complex human-nature relationship. Initially, I viewed the environmental issues surrounding Santiago's water supply from a technical standpoint. However, the fieldwork experience at El Morado, where I learned about the glaciers' role in sustaining rivers and hydrological systems sparked a shift in my perspective. I began to see how extractivist practices in the Andes compromise these crucial resources, disrupting the balance between hydrological systems and urban life. This experience highlighted the importance of examining environmental policies that are often anthropocentric and inadequate for protecting natural systems from exploitation. Through this shift, I started critically questioning power structures, recognising how corporate agendas drive socio-environmental conflicts, as evidenced by Alto Maipo.

This personal process of conscientisation underscored for me the power of research and education to challenge these systems. Working collaboratively with pre-service teachers, in-service teachers, scientists, and park rangers further enriched my perspective, revealing how diverse voices contribute to a transformative approach to science education that aligns with social activism. The collaborative nature of this project facilitated a shared learning experience, allowing participants to connect scientific knowledge with real-world socio-political dynamics and creating a space to question, reflect, and envision sustainable alternatives.

Furthermore, the dialogical seminars provided a unique opportunity for interdisciplinary exchange, where pre-service teachers, scientists, and park rangers brought different perspectives on environmental issues. For instance, discussions on the ethical and emotional aspects of outdoor education encouraged participants to consider their personal connection to nature, reinforcing the importance of empathy and responsibility. Understanding ecosystems as interconnected entities with inherent value, rather than merely as resources, enabled participants to connect their ecological and scientific knowledge to broader issues like corporate exploitation and environmental injustice. This approach fosters a critical scientific and environmental literacy that is not solely focused on knowledge acquisition but on developing a holistic view that encompasses social, cultural, and ethical dimensions.

In conclusion, this thesis shows that outdoor education is a powerful means to promote a critical scientific and environmental literacy approach. By immersing learners in real-world ecosystems, contextualising scientific knowledge within socio-political frameworks, and promoting interdisciplinary connections, outdoor science activities inspire critical awareness and ethical responsibility. This model of literacy aligns with conscientisation, and offers opportunities to reflect on the ways in which socio-political systems influence ecological outcomes and to consider how activism, collaboration, and collective action can address environmental challenges. Educating individuals to question the intersection of economic interests, environmental impact, and social justice not only empowers them to challenge unsustainable practices but also nurtures a commitment to informed, justice-oriented stewardship. Therefore, outdoor education is essential for fostering transformative engagement with science and environmental literacy, equipping learners to confront ecological and social crises with a proactive, ethical, and critical approach.

7.2 Contribution to knowledge

This thesis makes a novel contribution to the field of science education in several ways. First, it systematises international research concerning the concepts of scientific and environmental literacy (see Guerrero & Sjöström, 2024). This critical and systematic review of the literature from the past three decades on critical approaches is unusual in its consideration of multiple languages and global contexts. Thee review encompassed three languages, English, Spanish, and Portuguese, and integrated diverse voices, theories, ontologies, epistemologies, knowledges, and approaches to rethink science education and environmental education. In doing so, this thesis draws on studies from Latin America, Europe, Asia, Africa and North America to present a comprehensive understanding of how different regions approach environmental and scientific literacies.

Secondly, while existing studies have explored the concept of literacy through the work of Paulo Freire, this thesis extends this work by integrating the concept of environmental literacy and outdoor education. It thus introduces a new perspective, scientific and environmental conscientisation, thereby contributing to the body of work on scientific literacy through this expanded vision. Freire’s principles of critical pedagogy incorporated within science and environmental education might encourage students not only to learn about scientific concepts but also to question and challenge environmental injustices in their communities.

Thirdly, this thesis examines the opportunity to promote a *Latin-Americanisation* of science and environmental education, based on a social reconstructive ideology, on equity, transformation, multiculturalism and multiethnicity, and the professionalisation of teachers as experts who can contribute to the development of public policies and curriculum design, understanding science and environmental literacy as a collective endeavour. This perspective discusses territorial and contextual perspectives within formal science education, integrating the historical and local particularities of the region and considering local socio-environmental and socio-historical conflicts. This approach enhances the relevance of knowledge construction and suggests how the curriculum, for instance, can incorporate a more localised view of scientific and environmental literacy, for example, incorporating local environmental issues, such as Alto Maipo in Chile, into the science curriculum to make learning more relevant and impactful for students. This process is further discussed in Guerrero et al. (2024) with other scholars from Latin America, making this thesis a significant contribution to reviewing historical and current educational policy discourses in this area.

The science curriculum was also critically analysed and discussed, revealing areas for improvement (cf. Guerrero & Torres-Olave, 2022; Norambuena et al., 2023; Pérez et al., 2024; Salinas et al., 2023). This thesis therefore contributes to knowledge production in Chile, and Latin America more generally, adding relevant evidence to the current discussions about how to integrate holistic and critical perspectives from science and environmental education. Another contribution to knowledge is the conceptualisation of scientific literacy from critical theories and then applied to outdoor education (see Guerrero et al., 2023). It also considers the opportunities that outdoor education offers through interdisciplinarity and research-practice partnerships (Guerrero & Reiss, 2020) and the relevance of knowledge about how doctoral students can undertake collaborative and participatory research projects in the light of the COVID-19 pandemic (Guerrero & Dobson, 2024).

As a contribution to knowledge, I also propose addressing the integration of scientific and environmental literacy from a new *Vision* or a critical perspective based on Paulo Freire and called *scientific and environmental conscientisation*, which can be defined as:

> The ability to make informed decisions and act in the context of socio-scientific issues or socio-environmental conflicts through a critical examination of scientific knowledge while collectively integrating other forms of ecological and territorial knowledge.

Scientific and environmental conscientisation has the following principles: i) it involves politicised knowledge based on action (for example, climate activism), aimed at promoting the development of critical thinking for dialogic emancipation, socio-political action, and socio-ecological justice; ii) it emphasises transdisciplinarity and sustainability (from a contextualised and local approach); iii) it is oriented towards praxis and action; iv) it aims to articulate scientific literacies with socio-political, economic, and environmental dimensions; v) it makes references to collective experiences, reflections, and actions; and v) it investigates power relations and justice and incorporates elements of social reality transformation.

To develop this approach, we should first move forward to an explicit recognition of science teaching as a political activity. To achieve this, teachers should know, reflect, and problematise, from a local and global perspective, aspects such as the cultures and identities of communities, the dichotomous human-environmental relationship in their territory and their local socio-scientific issues, and recognise political, environmental and social tensions. This process might allow them to rethink and reflect about our interdependence with nature, the environment, and all human, non-human and more-than-human entities, promoting values such as responsibility and respect from a collective rather than an individual vision.

Secondly, to attain this aim, schools should generate spaces for meeting and collaborating with members of educational communities who have an interest in participating. The school in that sense is inserted into a broader framework, just as the communities insert themselves and break the walls of the school, for example, through partnerships and collaborations with universities, municipalities and other social organisation near the school territory. These partnerships could contribute to conserving spaces close to the community. This type of initiative involves a teaching staff that crosses traditional limits, manages networks and collaboration spaces, and promotes a dialogue that invites discussion for construction and transformation. This collective process requires that different voices and identities are mutually recognised.

Thirdly, this process requires the design of multi, inter and/or transdisciplinary teaching and evaluation situations in territorial contexts, using, for example, socio-scientific, socio-ecological issues as well as socio-environmental conflicts with which educational communities coexist daily in their territories. This could allow students to explain complex phenomena and take action to address aspects of the problems, for example, through the implementation of transdisciplinary school projects.

Fourthly, it is also relevant that we recognise the contributions of other knowledge systems and ontologies, such as those of indigenous communities. This not only involves understanding the relationship between human beings and nature, but also understanding our own human nature. In this sense, this approach is aligned with decolonial theories in the process of rethinking our extractive relationship with nature (Vivas, 2022), but also entails reviewing the imposition of norms and conceptions that contradict what had been conceived as natural at the moment of teaching or doing research in education.

Fifthly, I highlight from the experiences discussed in this thesis the contributions to the construction of public policies in Latin America that contribute to the permanent training of teachers as a situated learning process. In these, the specific context of the region influences critical professional development and leads to the construction of communities of practice that produce alternative curricular proposals for the approach of socio-scientific and environmental issues.

Scientific and environmental conscientisation in Chile and elsewhere requires education processes to be characterised by dialogue, which is established between academic peers, with the aim of creating teacher training processes in praxis. The latter process should allow and open new reflection and the implementation of novel curricular proposals that transcend the traditional interests of schools, instead offering students the opportunity to confront the socio-scientific and environmental problems of their contexts, from a scientific-technological, cultural, and socio-political perspective.

Finally, and taking a Freirean approach, I want to highlight that raising conscientisation scientifically and environmentally is, ontologically and epistemologically speaking, a process to ‘uncover’ reality. It is important to penetrate the phenomenal essence of the object, in front of which we find ourselves to analyse it. For this reason, conscientisation does not consist of ‘being in front of reality’ by assuming a falsely intellectual position. Conscientisation in science and environmental education cannot exist outside of ‘praxis’ or rather, without the act of action-reflection. This dialectical unity permanently constitutes the way of being or to transform the world. Precisely for this reason, this awareness process is a commitment, which is also historical and material consciousness; it is a critical insertion that implies that human beings assume the role of subjects who make and remake the world (Freire, 1979). Thus, the processes of conscientisation are not based on consciousness on the one hand and the world on the other; in other words, conscientisation does not assume a separation between world and subject. On the contrary, it is based on the consciousness-world relationship, from a scientific and environmental point of view, between consciousness-world human beings, non- and more-than-human entities, and nature. To tackle these issues, one needs to consider the school and the traditional education system at a broader level, (re)signifying formal education and looking for opportunities, for instance, from outdoor education.

7.3 General conclusion

As a general conclusion, it can be said that there are various ways to interpret and even merge the concepts of scientific and environmental literacy. Both concepts have been widely discussed in the literature over the past three decades and used as metaphors and hypotheses to regulate what should (or should not) occur in educational processes. It is important to continue questioning the use and objectives established in the name of literacy and how these concepts become social practices. How the word 'literacy' is conceptualised carries epistemological, ontological, and axiological implications, which align with the nature of science and the contextualisation of scientific knowledge. The conceptualisation of educating the population varies, depending on the ideologies and educational paradigms underpinning each context. Therefore, it is essential to continue studying this conceptualisation and how diverse *visions* or perspectives are embedded in teaching practices and, as seen in this thesis, in the training of future teachers, the environmental education provided by 'non-formal' educators, and the practices of science educators.

This thesis confirms the polysemy of both concepts and the complexity of addressing the concept of literacy, proposing the notion of conscientisation for the Chilean context and potentially for the entire Latin American context. This aims to develop tools that contribute to building a dialogue between scientific and environmental education, taking into account the political, social, economic, and ethical components that shape these disciplines.

The fusion of the concepts of scientific and environmental literacy is possible through the concept of conscientisation and becomes imperative in the context of the global climate crisis. However, this amalgamation should occur with consideration of the historical, material, territorial, and contextual realities of each specific country and 'territories'. Territory is a theoretical and methodological concept that describes how human social relations develop in cultural, social, political, and economic spheres. It is both an empirical reference and a theoretical concept. One approach to promoting critical scientific and environmental literacy is through education outside the classroom, such as visiting areas defined as zones of socio-environmental conflicts. The INDH map and EJAtlas presented in this thesis offer various tools to help address the territorial realities of students in different regions of Chile and Latin America. Both platforms serve as resources for gathering information and planning educational fieldtrips. Additionally, they help analyse networks between various actors, thereby expanding scientific and environmental knowledge to various interconnected socio-political and economic dimensions.

However, organising educational outdoor activities, particularly in science education, is not an easy task. As demonstrated in this thesis, pre-service teachers in Chile have few professional development opportunities during their university education to conduct such visits, resulting in limited pedagogical knowledge on how to organise, plan, and execute outings. This lack of training is connected to education policies which significantly impacts their expertise in handling these valuable educational instances.

To address this situation, this thesis demonstrates that collaborative and participatory research processes can play a central role in developing and strengthening expertise in outdoor education. Partnerships with key actors, such as park rangers, and other stakeholders, such as in-service teachers and science educators, were fundamental to advancing towards expertise. However, expertise should also consider critical theories and perspectives of the sciences to holistically address socio-environmental conflicts or issues related to the climate crisis. Without a critical perspective, traditional views of scientific and environmental literacies may be perpetuated, whether through outdoor activities or not.

In summary, promoting critical scientific and environmental literacy requires perspectives that go beyond the traditional classroom and embrace a collective endeavour. This perspective must address the dichotomy between humans and nature, raising awareness about the interconnection and interdependence of human, non-human, and, if pertinent to the context, more-than-human entities. Achieving this approach involves collaboration, interdisciplinarity, and the contextualisation of science to merge scientific and environmental education in times of climate crisis. It requires considering territorial realities and the systematic and historical processes of nature exploitation, as well as recognising the current crisis as a consequence in large measure of historical and colonial extractivism, and contemporary neo-extractivism and the neoliberalisation of nature.

7.4 Implications

7.4.1 Implications for practice

In terms of teaching, this thesis proposes moving towards a collective practice of teaching and learning science. A critical view of scientific and environmental literacy suggests understanding educational processes as social, political, and collective activities. Therefore, the processes of scientific and environmental conscientisation encourage teachers to collaborate with their students and various social and community organisations. This thesis has demonstrated the potential of dialogue and collaboration in strengthening the expertise of pre-service teachers.

Additionally, the thesis has evidenced that collaborative work based on interdisciplinarity enriches learning and contributes to developing more complex perspectives on social phenomena. Addressing an educational phenomenon from multiple viewpoints requires diverse experiences, identities, voices, and perspectives that go beyond the fragmentation and reduction of knowledge.

Furthermore, this thesis confirms the value of out-of-classroom learning in promoting profound educational processes. The expertise developed by the teachers in this project will directly impact their educational practice and the learning experiences of their future students. After visiting El Morado, participants felt more prepared and better equipped to organise and lead educational field trips. This experience marked a shift from their initial perspectives, as reflected in the final interviews, where many discussed new considerations and practical measures needed for planning such outdoor activities. More significantly, their understanding of scientific and environmental processes in outdoor educational settings deepened. For example, they recognised the glacier not only as a geographical feature but as a powerful illustration of the interconnectedness between nature and human life, highlighting the impact of climate change on ecosystems and local communities.

This thesis therefore demonstrates the vital role of out-of-classroom learning in fostering conscientisation. Such experiences can encourage participants to engage more critically with environmental issues, viewing nature as an active part of our socio-political world rather than a distant or abstract concept. For instance, discussions around the glacier and the controversial Alto Maipo hydropower project helped participants reflect on human responsibility in environmental stewardship, linking local environmental changes to broader issues of water management and sustainable practices. These reflections show how outdoor learning can nurture a deeper awareness of ecological and social responsibilities, inspiring a sense of agency and commitment to addressing socio-environmental challenges.

Regarding the park rangers, collaborating with teachers allowed them to develop new pedagogical perspectives that will contribute to their daily practices as environmental educators. While they may not consider themselves traditional teachers, their role as park rangers has the potential to support the educational practices of visiting teachers.

For science educators, this experience involved educational and collaborative processes to reflect on and promote critical perspectives on science education. Consequently, this thesis could have direct implications for training future generations of science teachers in Chile. The science educators involved in this project are responsible for training future teachers. From the experience gained in this project, they can share and introduce new ways of teaching science, thereby strengthening the expertise of pre-service teachers and enhancing the value of out-of-classroom learning.

For in-service teachers, this thesis provided valuable elements for their teaching practice: first, by explicitly involving them in research processes and collaboration with other stakeholders; secondly, through the reflective processes that occurred throughout this project, teachers became more aware of the ways, perspectives, and visions they have about teaching science in their specific contexts. The dialogical seminar was crucial in strengthening their expertise as teachers regarding out-of-classroom education. Moreover, this project presented new opportunities for them to address socio-scientific issues or socio-environmental conflicts in their contexts and with their students. These teachers now have the tools to conduct research and tackle problems in an interdisciplinary manner within their teaching practice.

Overall, this thesis underscores the importance of collective and interdisciplinary approaches in science education, the critical role of out-of-classroom learning experiences, and the ongoing professional development of both pre-service and in-service teachers. Through practical examples and collaborative efforts, it aims to foster a deeper understanding and critical awareness of scientific and environmental literacy among educators and students alike.

7.4.2 Implications for theory

This doctoral research has several implications for addressing existing theories in environmental science education. A relevant point from Marcelino and Tormöhlen’s (2024) findings is the analysis of how different authors are discussing and adapting Freirean ideas, particularly in formal education. This thesis contributes by applying critical theories and understandings of Freire to outdoor education, considering his revolutionary pedagogical approach characterised by dialogue, conscientisation, and empowerment. In particular, this thesis demonstrates the potential of critical theories to challenge traditional methods of teaching and learning science in out-of-school contexts (Guerrero et al., 2023). While these theories present complex challenges in politicising teachers, such approaches are essential for future research, especially considering the current emergency context in which we live.

Critical theories counter individualistic approaches and advocate considering the diverse experiences of individuals, empathetically respecting their realities and subjectivities. In this sense, experiences in out-of-classroom activities are unique and non-transferable. Therefore, critical theories based on Freirean ideas can connect with the everyday and collective realities that individuals live through in their own contexts. Learning outside the classroom is a didactic tool that provides numerous opportunities to question, learn, and act in the real world through a dialectical process.

Critical theories offer reference frameworks and lenses to create, produce, and ontologically question a social reality in particular contexts. For instance, they encourage educators to integrate local environmental issues into the curriculum, fostering a deeper connection between students and their immediate surroundings. This approach not only enriches the educational experience of students but also promotes a critical understanding of socio-environmental issues. Through the lens of critical theories, educators can facilitate learning experiences that are both reflective and transformative, enabling students to develop a critical consciousness and actively engage with their communities.

7.4.3 Implications for research

In terms of research, this work highlights the potential of addressing problems or challenges in education collaboratively, considering the voices of various stakeholders from different institutions and with different areas of expertise. Collaborating and tackling an educational problem collectively enriches the research process with diverse perspectives and can lead to participants being recognised as valid and expert actors.

This collective approach to research challenges the traditional paradigm in educational research, where teachers typically contribute data or experiences in a top-down manner. In contrast, collaborative and participatory research seeks to break this extractive method of producing evidence and knowledge, valuing and recognising all participants as co-researchers. For instance, in this thesis, teachers, park rangers, and environmental educators were involved not just as data providers but as contributors to the research design, implementation, and analysis. This method fosters a bidirectional collaborative alliance that aims to benefit the participants as well. By adopting this approach, the research recognises the importance of the collective input, ensuring that the findings are more holistic and grounded in the realities of those involved. Collaborative research thus becomes a tool for empowerment, promoting a more equitable and inclusive process of knowledge production. This shift not only enhances the validity and relevance of the research but also helps ensure that the outcomes are more likely to be adopted and sustained in practice.

7.5 Limitations

Some limitations of this project are related to the initial context of the research. When starting the project, my intention was to work with school children and then conduct the interviews and various sessions and workshops with the teachers in person. Although we transitioned to virtual sessions, this shift limited the hands-on, immersive experiences that are of particular value for developing a deeper understanding of environmental education in outdoor scenarios. The inability to meet in person to visit the park in advance, for instance, meant that certain interactive elements, such as direct observation and immediate feedback, were less ‘effective’ than they would have been in a face-to-face setting. However, due to the sanitary conditions imposed by the pandemic, face-to-face meetings were not possible.

Consequently, many of the collaborative research processes were not developed in the ideal manner that would have strengthened the research professional development of all participants. Moreover, it would have been preferable to prepare pedagogical materials for the teachers visiting the park as part of the final stage of the project. A significant limitation of the project was that its focus was more modest than initially planned. The original idea was also to work with teachers from other schools.

Furthermore, the planned evaluation of the teachers’ expertise in organising educational field trips after the completion of the project field trip was not carried out due to time constraints. This evaluation would have provided information about the practical skills and knowledge gained by the teachers through the project and would have helped identify areas for further professional development. It would have also provided insights into how well the theoretical aspects discussed during the sessions translated into practice.

The development of pedagogical materials tailored to the specific needs of the teachers and their students was another area where the project faced constraints. These materials were intended to serve as a practical guide for educators planning future visits to the park, incorporating the principles and insights gained from our research. The absence of these resources means that the dissemination of the findings and their application in real-world settings is limited.

The lack of implementation of a field trip with a broader group of participants is another key limitation. Such an activity would have provided valuable data on the practical aspects of organising and conducting field trips, including logistical challenges, student engagement, and the effectiveness of the educational content delivered. It would have also allowed for a comparative analysis across different schools and teaching contexts, enriching the overall findings of the project.

7.6 Further research

Future researchers can build on this work by exploring the practical implementation of scientific and environmental conscientisation across various educational levels. Studies could focus on developing specific curricula, teaching strategies, and assessment methods that embody the principles of critical scientific and environmental literacies explored in this thesis. For instance, future research might focus on the design of interdisciplinary curricula that integrate local environmental issues into science education, promoting a deeper connection between students and their communities. Additionally, innovative teaching strategies that engage students in critical discussions about socio-environmental justice could be developed and evaluated, at both primary and secondary level education. Some concrete opportunities are in the new Chilean subject 'Science for citizenship', implemented in 2019 but with a lack of empirical teaching evidence.

Further research could investigate the long-term impacts of these educational approaches on students' ecological and social awareness, community engagement, and problem-solving abilities. Longitudinal studies could track how students exposed to these methods develop a sense of responsibility and agency in addressing environmental issues over time. For example, examining the influence of outdoor education programmes on students' future career choices and civic participation would provide valuable insights into the lasting effects of critical science education.

Finally, expanding the research to other regions and cultural contexts in Latin America, Africa and Asia would offer valuable insights into the adaptability of the proposed theoretical framework. Comparative studies could explore how different communities incorporate local knowledge and practices into their educational systems, thus enriching the global discourse on environmental education. Researchers might also consider how indigenous knowledge systems can be integrated into science education to promote a more inclusive and holistic understanding of the environment.

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