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Place-Based STEM Education for Sustainability: A Path towards Socioecological Resilience

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Abstract: This article analyzes STEM projects conducted in eight schools with children from 4 to 10 years old in southern Chile. The main purpose of the study was to describe and analyze how these projects can affect students' and educators' attitudes and create community capacities to tackle local socioecological challenges. We used an ethnographic design with an intentioned coding process of interviews and participant observations to summarize one year of collaborative and transdisciplinary project building. The results describe the main attitudinal changes of teachers and students and give evidence on how these projects create new links and foster collaborations with local actors and organizations that are usually sidelined from educational experiences. Examples of meaningful learning experiences to tackle sustainability challenges were systematized and shared, to inspire new initiatives, raise new voices, and promote active participation of the new generations to foster socioecological resilience.

Keywords: place-based education; STEM education; education for sustainability; socioecological resilience; project-based learning

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1. Introduction

In 2018, the research journal Nature published a paper titled "Ecological grief as a mental health response to climate change-related loss", indicating the potential of the concept of "ecological grief" to better understand the psychological and emotional responses of both present and future scenarios of loss [1]. It identified three types of grief: that which is associated with physical ecological losses, with the loss of environmental knowledge, and with anticipated future losses. This last kind of grief linked to the anticipation of future losses will likely increase in prevalence, and may particularly impact children and youth who are currently growing up with "doom and gloom" narratives [2].

After one year of ethnographic research accompanying STEM-based projects implemented in schools in the south of Chile, this article shows how projects help to build resilience to face complex future scenarios at two levels: first, by building solid personal competencies and attitudes in children; and second, by strengthening local community capacities. In other words, this article will show how inquiry-based learning, outdoor exploration and place-based learning strategies applied to solve local challenges can contribute both to personal and community resilience, to face socioecological challenges.

First, we will clarify what we mean by STEM approaches, to provide comprehensive educational experiences in what we have called "STEM education for sustainability". After that, we will focus on the concept of resilience, applied to face socioecological challenges, understood as a process of transformation and adaptation at the individual and community level needed to face local and global social and ecological changes.

To put this into practice, we present a framework that defines five dimensions of local knowledge wherein curricular crosses can be made with STEM topics and present some exemplary cases where this has been put into practice by the implementation of project-based learning methodologies in schools located in the south of Chile, where indigenous, local, and scientific perspectives feed educational experiences. To understand how these changes affect individual and collective resilience, we will summarize the ethnographical journey of accompanying schools that developed annual STEM projects.

2. STEM Education for Sustainability at an Early Stage

Science, Technology, Engineering, and Mathematics Education for Sustainability (STEM4S) encourages children and youth to draw on their STEM competence and the process of science as a key basis for reasonable action in our world. Knowledge, skills, and an understanding of science, technology, engineering, and mathematical phenomena contribute to developing citizen foundations to understand global problems and support actions in society that address these challenges in a meaningful and knowledge-based way. The STEM4S approach promotes advocacy not just for workforce development (a traditional argument of why STEM education matters), but for developing students' critical thinking and sustainability mindsets, habits of using scientific evidence to justify sustainable practices, and understanding the value of STEM education for society as a whole [3].

The orientation of individual actions toward certain explicit and reflective values enables us to act locally in such a way that we also take responsibility for the world around us—combining our "personal identity, local identity and global identity" [4] as we use the STEM framework to enact social good. STEM4S can promote raising reflective change-agents to impact their communities and society through a knowledge-based, action-oriented, participatory and integrative focus [5]. To create environments that foster agency through inquiry-based learning, STEM4S must integrate STEM fields of knowledge and experience with social and emotional learning and civic engagement. Children need to be considered active stakeholders in inquiry and sustainability issues and to be encouraged to become problem seekers and solvers in their localities [6].

This relates to the relevance of scientific literacy among young children. They need to learn to undertake science in a wide sense. This means an interdisciplinary scope to acquire scientific competencies through practice, which presupposes the integration of fields to address practical issues [7]. Furthermore, STEM4S can be linked to the active involvement of the local community. This calls for integrating science-based knowledge and its value for society with other forms of knowledge present in the locality in a way that transcends any discipline on its own to collectively address a common problem, transiting to a transdisciplinary focus. Here, STEM and social science techniques are considered together with local knowledge, stories, narratives, traditional practices, wisdom, and collective intuitions into the school practices and contents, acquiring new significant importance, especially regarding urgent topics to tackle socioecological resilience [8,9].

Furthermore, according to Ferreira et al. [10], education for sustainability reinforces a systemic "whole institution approach" focused on the development of the educational facility as a whole and considers not only the role of the early childhood educators or primary teachers but also school leaders, community or state leaders, or other decision-makers at the educational management level [11].

3. Towards Socioecological Resilience

Resilience is a wide concept that in general can be understood as the capacity of adaptation and transformation to external changes. Resilience is not necessarily a positive term, and it is often misconceived in the field of education, through an incomplete understanding of its adaptive nature and through not considering resilience for whom or to whom [12]. It is therefore very important to make a clear definition of what we understand and the limits of the concept in the context of this paper.

Recent research explores the way in which environmental education relates to personal and systems resilience [12,13]. Chawla et al. [14] found that contact with nature in school allows kids to find peace and to build social competencies and cooperative social relationships. In this sense, educational opportunities that provide contact with nature can be by themselves a form of resilience, by helping to deal with stressful situations and change.

However, this is insufficient, as resilience from a socioecological perspective is much more complex and depends both on personal and collective characteristics. Cretney [15] defines socioecological resilience as "The interplay of factors involved in recovering from disturbances, re-organization and the development of socio-ecological systems," and highlights the critical importance of the community in this process. After making a comprehensive review of the term in the literature, one of the interpretations the author gave, critical to our research, was of resilience as a radical transformation to socioecological issues emerging from grassroots initiatives. Here, the social capital and community capacities are marked as central [16,17].

Social capital is related to the interconnectedness and networking capacity of a particular community, its civic engagement, local identity, cooperation, and levels of trust [18]. It considers both bridging connections (connections with people outside of the community) and local connections (the number and density of the internal networks). The social ties are crucial, considering that high levels of social capital in a community are related to lower suicide rates, lower mortality, and longer life expectancy [19,20].

Relative to our study, the capacity of educational institutions to build and enhance social capital in their communities is key, by making local collaborations and connections with strategic organizations and people outside of the school community. Here, the idea of transdisciplinary STEM4S projects is central, as a methodology for science-based projects that integrate not only knowledge from different disciplines but also other sources of knowledge outside of traditional academic areas [21].

4. STEM4S and Local Knowledge

This article analyzes how STEM4S projects interact with local communities and traditions (specifically, the Mapuche culture, which is very important in the Araucanía region), without neglecting the current curriculum in Chile. The aim is to connect schools with local realities, to generate a broad conceptual framework that makes teaching interact with traditional and everyday cultural knowledge of both the Mapuche people and other forms of knowledge in other regions and countries. The word Mapuche means people (che) of the land (Mapu), and its worldviews and practices are, as in many Amerindian and oriental cultures, intrinsically ecological through the recognition of humans, plants, bodies of water, and other beings as co-inhabitants [22]. Opening the scholar culture and making it permeable to these worldviews under a broad understanding of what science means can make a big change in the challenge of biodiversity degradation; here, we provide examples of socioecological resilience practices that have emerged from educational practices.

Parents and adults in the children's environment are knowledge managers and model the way to transmit it, either through play or in the daily chores inherent in community and home life [23,24]. Studies that have focused specifically on Mapuche ways of learning have observed that the figure of teachers as such does not exist and that, instead, there is an image of wise people who transmit knowledge through interaction and the sharing of daily spaces rather than by formal means [25,26]. In this adult–child relationship, few "orders" are observed; instead, the autonomy of children in resolving the situations they face is privileged [27].

The school can dramatically break local ways of understanding learning and the relationship with adults, setting new forms of relationship and structures. The contents to be acquired lose their experiential character, often becoming distant or not very understandable for the students, and where the teacher acquires the central role in the classroom, being the one who orders and shapes the practices and ways of learning. However, this situation can be reversed and redirected by the school through the inclusion of pedagogical practices that integrate the students' previous knowledge, as well as the dynamics of learning in their cultural systems [28].

As Luna et al. [29] propose, it is necessary to design a meaningful experience for the student and with it generate a different way of understanding learning. It is important under this perspective to situate the learning, i.e., giving it a practical and contextual sense. In this line, Tiburcio and Jiménez [30] indicate:

> " ... *if the school environment is organized and structured concerning significant content for students through tasks that involve creative and conscious participation, they will develop and build learning from the dialogues and socialization of knowledge and the social perspective of these practices.*" (p. 129)

Educational institutions must tend toward a balance between pedagogy and methodology dialogue through combining the use of teaching methods that are formal and non-formal, as well as modern and traditional [23,31], thus revealing the social contexts in which the school is inserted and with it its associated practices. Local knowledge can be a facilitator for understanding the natural environment, climatic phenomena, and physical and chemical processes present in the daily activities of communities surrounding the school. In this sense, there is a direct relationship between local ways of learning and the proposed methodology for inquiry-based learning proposed in STEM4S.

Bascopé and Caniguan [32] built a research-based framework in conjunction with teachers, indigenous communities and families, which resulted in five domains in which local knowledge can be connected to the school curriculum. This cross between the curriculum and local knowledge can be easily extrapolated to other contexts, so it can be a valuable input for the creation of further pedagogical activities and resources in Chile and other countries. To reach these domains, the authors conducted a comprehensive work with a group of schools and their external communities during 2014 and 2015 based on in-depth interviews with teachers, traditional educators, families, and indigenous community leaders [32]. After a systematization and coding process, the five domains were established and crossed with the Chilean national curriculum to analyze how well they fit with curricular objectives, finding a great number of objectives per dimension all over the primary curriculum. The following is a brief explanation of these domains and their applicability for STEM4S projects:

1. *Health and the human body*: Medicinal herbs are an important subject and are used daily in Mapuche communities. Therefore, the incorporation of the recognition of these herbs and their relationship with the healing of certain parts of the human body are contents that can be developed within and outside of the classroom and can be complemented with particular knowledge regarding native flora and its physical characteristics.
2. *Traditional foods and culinary processes*: Cooking and food preparations represent another area in which both scientific and cultural knowledge can be developed. This knowledge shows processes of fermentation, dehydration, and decomposition of food that allow its preservation. From this knowledge, which belongs to the domestic sphere, the chemical and biological processes that constitute it can be reviewed, thus becoming understandable.
3. *Crafts and tools manufacture*: Tool manufacture, goldsmithing and other crafts are of great importance to the indigenous peoples. The dyeing of wool with vegetable species is an ancestral practice. All these processes are considered as eminently scientific knowledge that in the homes are recognized as traditional knowledge learned in the practice, observation, and transmission of the elders. The same happens in the case of goldsmithing and making tools for solving daily problems.
4. *Ecosystems and agriculture*: The recognition of flora and fauna, local tales about different species, and the relationships among them are embedded in previous generations' narratives. For example, the types of soil found in their territories will be fundamental in determining the agriculture and types of sowing to be developed, as well as allowing for activities such as pottery, work with vegetable fibers, or others, according to the species found in their spaces. Reading the signs of the weather and the environment is knowledge that, furthermore, affects agricultural and domestic work.

5. *Worldviews and spatial–temporal notions*: There are local ways of measuring time to guide domestic work, ceremonial work, and other tasks. Thus, systems are created to record the time in which one carries out or should carry out certain activities. For example, the knowledge of certain natural cycles allows the most appropriate moments of the day for performing certain agricultural activities.

Although the five domains seek to connect local knowledge with the scientific paradigm, this knowledge should not be trivialized or simplified to the codes of scientific thought. On the contrary, the mere inclusion of these topics opens a space for the generation of debate on historical–cultural issues or on ancestral worldviews, which, despite not directly agreeing with the scientific perspective, allow the learning of the official curriculum to be placed in a dialogue with other worldviews.

This proposal of domains to start a dialogue between local and scientific knowledge was the first step to start building STEM4S projects in joint effort of educational institutions, the university, and local actors, to tackle specific socioecological challenges of their communities and territories.

5. Research Guiding Questions

The research had an exploratory focus, intending to gain teachers' and educators' perspectives on the implementation of STEM4S projects, based on local knowledge. The goal was to describe the implementation of these projects and understand the main lessons learnt and changes—at individual and community levels—after one year of implementing a project to tackle a local sustainability challenge. The starting point considered the following guiding questions:

- What were the main scenarios selected to conduct STEM4S projects and how were different dimensions of local knowledge considered?
- What was the role of students, teachers, and community actors during the implementation of the projects?
- What were the main changes and learnings achieved after one year of implementing STEM4S projects?

After the implementation of the projects and during the coding process, "socioecological resilience" emerged as a comprehensive concept to understand the consequences that the projects had at different levels (students/teachers/community). This article provides a first exploration of how these kinds of projects can contribute to building personal and community resilience.

6. Implementation of STEM4S Projects

6.1. Description of the Ethnographic Work

The research was based on ethnographic work carried out in 2019 that emerged from a collaboration between a teacher training program and eight schools interested in working on STEM4S projects for one year. The age range of the students involved in the projects was from 4 to 10 years old and at least three teachers from each school participated in the initiative. The results systematize the schools' experience based on classroom and fieldwork participant observation, and interviews with participating teachers. Therefore, the study has an ethnographic scope, with the researchers as active participants in the process of building the projects and accompanying the groups through the process.

Teachers were invited to a series of three workshops with the objective of planning and implementing research projects with their students. The topic of the projects focused on learning about the school surroundings and tackling local socioecological challenges. In collaboration with university scholars, organizations around the schools, and the school community, teachers and students planned research projects and implemented them during one complete school year.

The first workshop at the beginning of the first semester was focused on describing the school's territory and identifying local challenges that the project could address. Each school team built a model of the school and its surroundings using building bricks and made explicit connections with the five domains presented at the beginning of the workshop. The domains were used to elicit possible socioecological challenges where local and scientific knowledge could contribute. Teams then listed possible challenges and formulated research questions in collaboration with researchers from the university. They took a group of questions to discuss with their students using a similar methodology and came back to the second workshop with a reformulated research question after the discussion, based on the students' interests and prior knowledge.

After one month, in the second workshop, we printed three maps of the school at different scales (1 km, 10 km, and 40 km around the school) to start planning the research project. The idea was to operationalize the research question by identifying on the maps participants and possible fieldwork opportunities depending on the project. A team consisting of one ecologist, one geographer, one sociologist, and one designer (all of them were researchers from the University) helped to plan the different projects, giving advice on sampling, possible fieldwork experiences, developing interviews and observation guidelines, and selecting participants. After one complete day of planning, teachers produced a timeline of the entire research process and arrangements were made to organize the follow-up process.

Now was the time for the researchers to visit the schools and work in the field. Monthly visits to each school were organized and, depending on the school requirements, they consisted of monitoring fieldwork experiences, making connections with scientists related to the research topic to visit the school, or connecting the school with other relevant actors (e.g., farmers, indigenous leaders, or social activists) that had contact with the university from previous projects. The university team also assisted in planning sessions, to help teachers prepare their lessons and fieldwork experiences, and to support the process of data analysis and working on the results.

It should be noted that each research project aimed at creating a clear result that was a product or solution to the local socioecological challenge identified. After the implementation of the fieldwork and analysis of each project, a third workshop was conducted. This last workshop was made to evaluate the process, show the main results and products, and plan on how to communicate this initiative to the local community.

After the last workshop, we organized three events in three different cultural hubs located in schools' local area to showcase the results and products to local communities. Children were able to present to and engage with their local communities about what they had learned and produced after one year of implementation of STEM4S projects.

During the whole process, we collected field notes and noted descriptive observations. We also recorded and transcribed 14 interviews with teachers. All ethical aspects were considered and approved by the University's committee of research ethics and informed consent was properly signed by directors, teachers, and parents. All data was coded intentionally to understand the perspectives of the teachers about attitudinal changes both in teachers and in students and to analyze differences in community involvement before and after the implementation of the projects.

6.2. Data Collection and Coding Process

6.2.1. Semi-Structured Interviews

Interviews with participant teachers and educators were conducted at the end of each project. We developed a simple rubric with five topics to comprehend the process and impact of each project at different levels, including students, teachers, and the community. These topics and the main guiding questions are presented in Table 1.

Table 1. Topics and guiding questions for the interview process.

Interview Topics	Guiding Questions
1. Analysis of the implementation of the project	How was the experience of implementing a one-year project?
1.1. Collaboration inside of the school	Did you receive support from your colleagues?
1.2. Relationship with the community	Did you find external partners for the project implementation?
2. Main lessons learnt and changes	
2.1. Student level	What were your students' main lessons from this process? Did you notice attitudinal changes among your students?
2.2. Teacher level	What were your main lessons learnt? Did you notice any attitudinal changes in yourself?
3. Main difficulties and challenges	What were the main difficulties and challenges to implementing the project? (external/internal)
4. Contribution to the local community.	Do you think the project contributed to your local community?
5. Expectations versus reality	Did the project meet your expectations?

We coded the interviews starting from the structure of the interview topics and used "en vivo" coding to capture emerging codes within each topic [33]. Five interviews had to be double-coded to define the emergent codes, using a criterion of saturation of emerging codes, stopping the double coding in interviews in which no new codes emerged. After that, other interviews were coded by only one researcher.

After coding all interviews, the en vivo codes were classified in two main "code trees" [33], using the socioecological resilience framework to divide the codes in relation to individual and community resilience-related codes.

6.2.2. Participant Observations

Participant observation was also semi-structured, with a focus on three main domains. There was a monthly visit to each school, where the researcher compiled notes with observations both in the classroom and in fieldwork activities in each school. All observations were conducted by the same researcher and then shared in monthly meetings with a pedagogical team at the university. The domains and aspects to observe are presented in Table 2. Field notes were analyzed under this three-domain structure; the criteria to report a result was that the description was present in the majority of the projects (at least 6 of 11 projects).

Table 2. Guidelines for the participant observation process.

Domains and Subdomains	Description of the Field Notes Domains
1. Interactions	
1.1 Student/educator	Description of the way the teacher interacts with the students.
1.2. Student/student	Description of the interactions between students
2. Learning focus	
2.1. Autonomy/control	Describe if children have spaces of autonomy during the activity
2.2. Space for exploration	Describe if children have the chance to explore and experience using all their senses
3. Content	
3.1. Local and global relevance	Describe how the activity is linked with local or global relevant aspects
3.2. Interdisciplinary focus	Describe how the activity incorporates knowledge from different disciplines
3.3. Local knowledge	Describe how the activity incorporates non-formal or non-academic sources of knowledge

Using the information of the observations and the codes that emerged, we decided to divide the projects into two kinds, depending on the main scenario where the project was developed. These projects shared similarities in terms of the relationship with the community, students' involvement, and content. To make more in-depth descriptions of the processes, two examples were selected as representative of the main results—considering the length restrictions of a scientific paper—to give an idea of the process, detected changes, and community involvement in these kinds of projects.

All data concerning participant schools, educators, and teachers is strictly anonymous, and each participant signed informed consent of their participation in the research process, which was previously approved by the university's ethics committee.

7. Results

7.1. Resulting Topics and Scenarios for STEM4S Projects

To start with a big picture of the resulting research topics, we built Table 3. Here, we summarized the research questions, partners involved in the process, and the main contributions to the community. Here, we made an effort to summarize the resulting projects using the methodology described above. Eleven projects resulted since three of the eight schools implemented two parallel projects with different age groups.

Figure 1 shows the great diversity of topics, questions, and participants. It represents the flow of the project-building process, from the five-dimensional framework to specific topics. To organize the presentation of the results, we classified the projects according to the main scenarios where they were conducted. We divided the scenarios into two kinds, outside and inside facilities. For outside facilities, we found that there were different useful landscapes (forests, wetlands, rivers, and orchards), but for inside facilities, educational green gardens were recognized as the main and only setting to conduct these kinds of projects and it was connected with a diverse range of research topics (see Table 3).

We analyzed the results with a focus on these two scenarios, raising examples that emerged in the coding process on how this affected attitudinal changes (in teachers and students) and on how they contribute to strengthening links with the community. After that, we provide two examples of the implemented projects to give a descriptive and concrete overview of how socioecological resilience was achieved with the projects. Finally, we provide a section with the main challenges detected during the implementation of the projects to provide useful information for similar initiatives elsewhere.

Table 3. Projects' research topics, questions, and relationship with the community [1].

Project Topic [2]	What Was the Research Question?	Who Was Involved from the Community?	What Were the Main Contributions to the Community?
Bird and tree networks (4 to 6 years)	Which birds and trees can we identify? Are birds and trees connected?	Parents, local bird keeper, two ornithology experts, local park ranger, the local librarian.	Artistic representations of birds and trees, theater work for the local community.
Local seeds projects (5 to 6 years)	How do seeds work and which local seeds can we recognize?	Local farmer, local food producer, parents, grandparents, an ecologist, a sociologist.	Book with pictures and descriptions of seeds donated to the school library. Donation of plants to the garden by the family of one of the children.
Traditional medicine_1 (5 to 6 years)	What can we do to preserve and revalue local medical herbs?	Traditional medicine woman, parents, local neighborhood authorities, two researchers (anthropologist and ecologist).	Production of a medicine kit for the school, creation of a school medicinal garden.
Traditional medicine _2 (4 to 6 years)	How are medicinal herbs produced and used? Lessons for our families and local actors	A doctor from the local care center, local traditional medicine woman (Lawentuchefe), local indigenous authority, local producers, parents, grandparents, local neighborhood authorities.	Creation of oils, ointments, and herbal teas. Donation of a medicine kit to the local care center. Creation of a short guide with the products proprieties and characteristics
Edible green gardens_1 (4 to 6 years)	What food can be produced in different seasons?	Local food producer, indigenous authorities of the local community, parents, grandparents,	Creation of a growing calendar including seasons and moon phases. Organization of community-based seed exchange.
Edible green gardens_2 (4 to 6 years)	What differences can we find between traditional green gardens and modern food production?	Local medium scale food producer, traditional Campesinos, parents, grandparents, three researchers (an ecologist, an agronomist, and a sociologist)	Creation of a biodiversity map of the different gardens visited, featuring plants, herbs, and insects.
History of wetlands (6 to 9 years)	What stories and physical evidence of change can we find in the wetland caused by a dam near the school?	Parents, grandparents, secondary vocational school students and teachers, local park ranger, three researchers (sociologist, ecologist, and geographer).	Literary production based on the research, map construction of the area identifying species and key areas.
Mammal monitoring (9 to 10 years)	What mammals can we find around the school?	Park ranger, a local landowner (livestock), parents, a biologist, an ecologist.	Video production with the evidence recorded showcased to the community. All the results were uploaded to an international database for mammal monitoring
Local water pollution (9 to 10 years)	How does human activity affect water quality and plants and animals on riverbanks?	Parents, local park ranger, local indigenous authority, two researchers	Presentation of the results to the local community and authorities, with a plan to preserve and restore the river.
Forests and reforestation (4 to 8 years)	What trees can we find in around the school land what can we do to regenerate the native forest?	Two local companies, two local organizations (neighbors and the water supply committee), parents, a local nursery garden, a local librarian, two researchers	Artistic representations of trees and plants, musical composition to the showcase to the community. A greenhouse to grow native species, managed by the students and educators, was installed in the community near the school
Local food exploration (6 to 8 years)	Can we rescue local knowledge about traditional recipes based on the native forest fruits?	Two local food entrepreneurs, parents, local forestry businessman, two researchers (an anthropologist and an ecologist).	Production of a recipe book based on local knowledge, local food showcase.

[1] More information about the projects can be found at http://www.eputrokinkimun.org (accessed on 21 July 2021). [2] In parenthesis the age group of the students involved in each project.

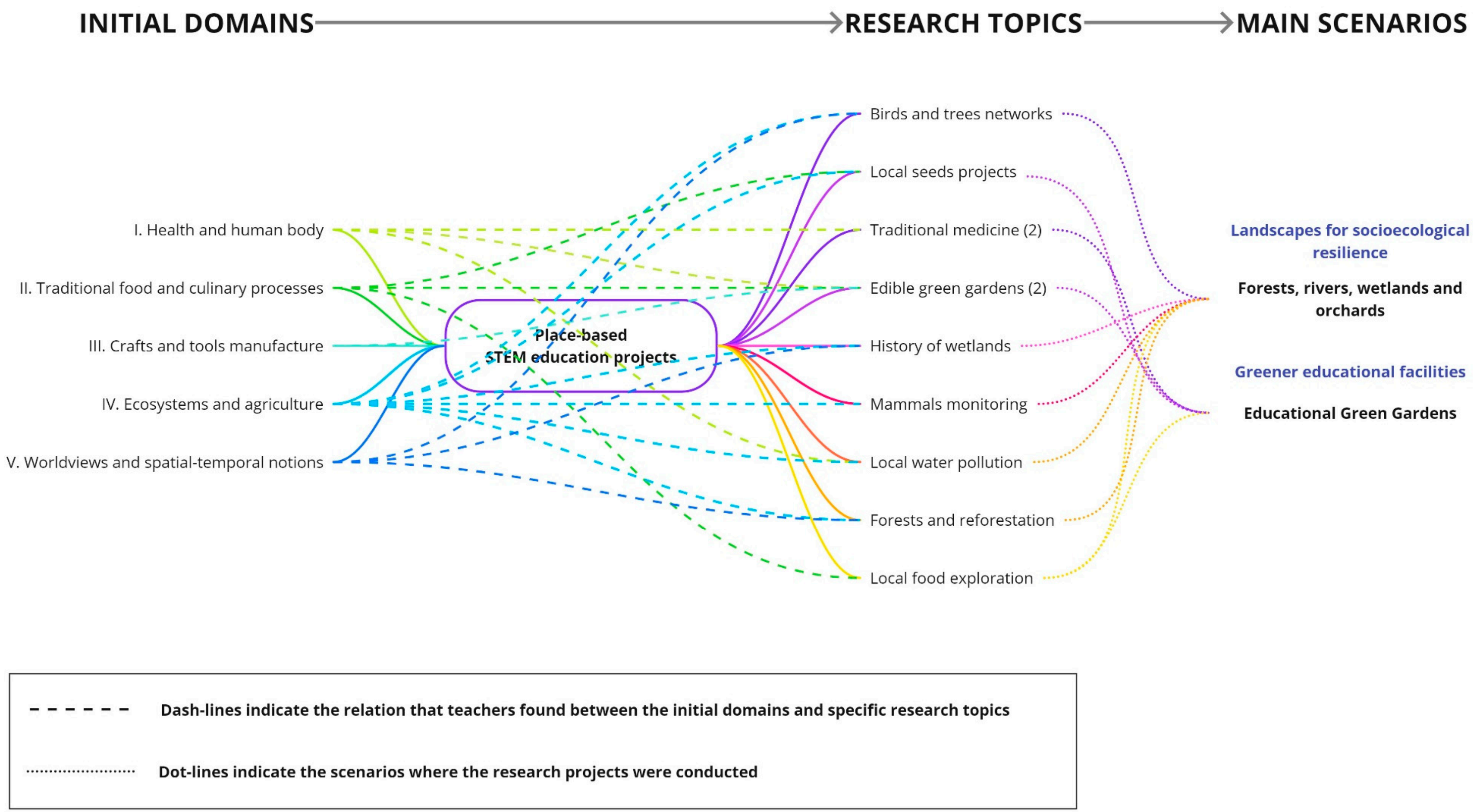

Figure 1. Resulting research topics and scenarios for STEM4S projects.

7.2. Educational Green Gardens: Greener Educational Facilities

Educational green gardens involved different kinds of projects: two traditional medicine projects, two projects about food using edible green gardens, a local seeds project, and one project on discovering and foraging for ingredients for traditional recipes that use native forest fruits, fungi, and plants.

Green gardens became a natural laboratory. We found them in schools in different ways, both as places with large growing areas or with adaptations to small spaces with intensive growing techniques. They can become interesting feasible projects with multiple resources to conduct educational experiences in a wide variety of topics. The focus might be on seed recognition, food production, growing medicinal herbs, and the production of oils, ointments, infusions, or poultices, depending on the research topic.

We also observed diverse methods on how local knowledge was brought to school. All activities were full of scientific and local knowledge and included planning the visits of different local and scientific experts on the topic, making practical workshops on seedbeds, cutting techniques, harvesting, greenhouse maintenance, efficient watering, and understanding timing for the different activities depending on the moon phase and season of the year.

The schools visited different types of operative green gardens outside of the school, such as traditional biodiverse orchards, monocultures or herbs and botanical gardens, all to acquire a wider and critical perspective on the objectives and possible ecological consequences of the different kinds of production. At the same time, teachers revealed high levels of practice-learning both by them and their students, applicable to their own daily lives; as one teacher revealed in her interview, *"I never imagined that this project would affect my perception of my role as a teacher, I've learned so much during this process, now I feel like I can really contribute to our community"*.

We found a very attractive opportunity to generate intergenerational exchange with the elders. The memory about traditional methods, the characteristics of the different plants, usages, and properties is found in grandparents and local elders. Compiling stories, interviews, and videos of these testimonies can be a productive way of socioecological resilience, to transform and adapt to the degradation of local ecosystems, by recovering the biocultural heritage of the elders, and also a way to contribute to more sustainable practices and personal know-how to achieve partial food provision or complete food sovereignty.

Some difficulties and challenges of these scenarios are the continuity of the green gardens during school vacations and the capacity of working with large groups on gardening topics. For the second problem, small-enrolment schools have an advantage and larger schools decided to work on the project with a voluntary science club, which became very popular after the first year of work. Regarding the school vacation problem, there was an idea of growing plants in portable wood boxes altogether in a greenhouse, and during vacations, every child takes a box with them to take care of during the summer.

In terms of attitudinal changes, teachers reported more motivated children and found in the projects a way to provide active learning opportunities. Teachers mentioned that fieldwork and learning with a tangible purpose gave space for development to those children with difficulties with learning in traditional school settings, giving space to explore with other senses and being able to make a valuable contribution to the projects. Additionally, teachers reported an increase in the students' levels of self-esteem, enjoyment of learning, and teamwork capabilities.

All of these findings relate to previous findings in the literature about the importance of greener schools as a resilience tool [14]. Moreover, teachers also reported that the projects change their students' attitudes towards science, *"They [the children] now feel more confident about sciences, they understand the role of the scientist and now they don't see science as something strange or distant."* Evidently, the experience of the projects also contributed to the first steps towards scientific competencies, making science more fun and with a clear sense of purpose, giving space to develop scientific competencies to act for a better future.

7.3. Forests, Rivers, Wetlands and Orchards: Landscapes for Socioecological Resilience

Some projects covered pollution of rivers, lagoons, and lakes near a school; the reforestation of surrounding areas in collaboration with local partners; biodiversity monitoring both by making aleatory samples of biodiversity plots, or more sophisticated ones using camera traps; and a project researching the historical consequences on the landscape after the installation of a dam for the electricity industry.

In these kinds of projects, outdoor field experience was necessary, and projects with more accessible and intensive fieldwork were more often qualified as meaningful by the participant teachers. There were also cases where teachers coordinated the visit of a scientist or specialist to the school to plan fieldwork, or to learn about certain topics. Here, the preparation of the fieldwork becomes crucial and was not always fully planned. After the experience, visits that were planned together with the students were much more productive than the ones that were planned exclusively by teachers; students were more engaged with the objectives and collected better data. Sometimes, the first fieldwork experience was a way to learn "what not to do", and second and third visits were planned to gather sufficient information for analysis.

Field measurement and sampling techniques were usually new for teachers, parents, and community members, and the collaboration with an active researcher was appreciated by the participating teachers. In this sense, the first experience of collecting data was a lot less productive than the following ones. Here, know-how is key and also improves the capacity to plan. On the other hand, the monitoring process of flora, fauna, and local pollution sites was a very entertaining and direct way to make a rather small but serious contribution to the local surroundings. In urban areas, the biodiversity comparison of an urban green area with a park outside of the city, the measurement of native flora in local parks and reforestation, the counting of existing native mammals with camera traps, and the water quality measurement were fulfilling experiences for children and teachers.

Teachers were the unexpected agents of change in the projects. The great majority reveal a surprising personal effect of the projects on the role they have in the community and what they can be able to achieve. Even though they were expecting this to happen to the children, they did not expect that the experience could also change them and were very willing to continue next year, find new partners, and convince new colleagues.

7.4. Building Socioecological Resilience: Two STEM4S Projects Examples

Regarding the influence that the projects had in terms of social capital and community resilience, two examples can be illustrative to understand the impact they had on the community and local environment. Even though the projects were conducted by children under the age of 10, they were very effective in creating new bonds with local actors and organizations that never had the opportunity to interact with schools before.

The first project was conducted by first graders (6–7 years old), centered on researching traditional medicine and medicinal herbs. They visited a local medicine woman (Lawentuchefe, in Mapuche language) to conduct an interview and visit the premises where she makes essential oils and ointments. They also started a research process with their parents and grandparents to collect local knowledge on the topic. In the meantime, they started to collect and plant medicinal herbs in their school, creating a medicinal green yard in their school.

The children later adapted the laboratory in the school to make oils and ointments, and dried medicinal leaves and flowers to make herbal water and build a medicinal kit with a short guide made by the children with information about herbs gathered during the process. The medicinal kit was donated to a small medical center in the village where the school was located, and first graders were the main participants in a ceremony held by local authorities in which the medicinal kit was donated. The connection with local actors, the school's extended community, and local organizations were completely beyond leading teachers' expectations, enhancing local resilience by increasing the community's social capital. The children also understood the importance of biodiversity and increased their awareness of the importance of forests and local ecosystems in preserving species and associated knowledge.

The second example was conducted by first and second graders (6 to 8 years old) in a school located in a small village that is almost completely dependent on the forestry industry. The landscapes around the school were mainly monocultures of pine and eucalyptus, covering all horizons. It is a village mainly populated by old people since the new generations prefer to migrate to bigger cities searching for opportunities.

The children decided to learn about traditional food recipes made with fruits of the forest, mainly based on what can be collected directly depending on the season. To do so, they started researching in their families about this, and gained attention from parents and grandparents who have seen the process of deforestation and loss of biodiversity around the village. A lot of tales about big and biodiverse forests, before the forestry industry started, were collected, with nostalgic and sad testimonies. One of the parents offered her land for the fieldwork, which was an ideal location as half of the land had a monoculture and the other half a native forest with mature trees and considerable biodiversity. The children collected samples and ingredients for the recipes and drew comparisons among the types of forests.

The school had a technical specialization in gastronomy, so in collaboration with the oldest pupils of the school, they prepared a sampling of local recipes open to the community. The event was a great success; in the words of one of the teachers, *"it was a very emotional and unforgettable experience, it helped us to understand what we are losing, and how important is to create value based on our roots and local traditions, for new generations to contribute to the sustainable development of our town"*. Again, new contacts, local stories, and techniques were collected, strengthening community resilience, and making teachers and students active agents for change in their localities.

7.5. Main Challenges for the Implementation of STEM4S Projects

Nevertheless, there were also unsuccessful experiences, especially when institutional conditions went against these kinds of innovations. Output-oriented schools and ambivalent leadership—principals that verbally supported the project but who did not give the necessary time and support to action it—damaged the projects and overwhelmed teachers after project completion, or with projects unable to be finished. Fieldwork preparation is time-consuming, which is why collaboration among teachers and other outside partners is key for the implementation; those teachers that involved parents, local contributors, and university staff were much more comfortable with the projects afterwards.

Another important caveat to consider for the implementation of these projects is what we called curricular anxiety. These kinds of planning invert the usual fashion of teacher planning that goes in from the national curriculum to the planned classroom activity. The projects proposed here were the other way around, from a specific problem to the curriculum, and that reversion led to anxiety about the alignment of project activities with the curricular objectives that teachers have to account for with their authorities and with parents and tutors. A teacher said at the end of the first workshop, when we were defining the question and objectives based on local problems, and making a circle to share feelings about the first day of work:

> *"This all sounds beautiful, very interesting, but what do I take home for my lessons? I'm used to going to a workshop and coming out with a proper set of guides and resources for my lessons, now I'm leaving with a big piece of homework that I don't even know if it will be related to the contents I have to teach." (Teacher in the feedback session after the first workshop)*

This teacher did not come back to the second workshop, and two schools left the project after the first workshop. At the second workshop made with teachers, we conducted a planning session to make a chronology of activities needed to be made to fully conduct the research projects, and a curricular adaptation relating every activity with a specific curricular objective. A great number of possible crossings were observed in the topics of mathematics, biology, chemistry, technology, language, and arts, and there was even a case where the sports teacher dedicated some fitness lessons to gardening labor. Therefore, this can be considered as an all-in-one project setting, with the versatility to be adapted to different sections of the curriculum depending on the stage of the research.

This frightening feeling was also present in many of the attendants of the second workshop, but the positive surprise after ending the second session —wherein everything was resolved and aligned with the curriculum— was transversal; a common comment heard both by trainers and teachers participating in the final feedback round was: *"I never imagined that I could cover that amount of topics with only one project."* Even though daunting at the outset, complicated problems can become very useful educational resources.

8. Discussion and Conclusions

After revising the topics, scenarios, and main results of this ethnographic journey, some reflections about the concept of "socioecological resilience" are needed. First, this concept has to be considered as an emergent concept during the coding process, after the implementation of the projects. The exploratory focus of the project started with wide questions about the implementation of STEM4S projects and there was no initial intention to explicitly measure socioecological resilience.

Thus, this exploratory article opens new research paths for a better understanding of schools' role in the creation and promotion of socioecological resilience. On the one hand, more advanced techniques to measure social capital and changes in the community capacities after the consolidation of these educational methodologies can be of great support to the field, incorporating measurements of social ties and connections, previously used in health and social sciences, to the educational sector, deepening on the schools' roles in this area, starting for early ages [17,19,20,34].

One possible criticism of community resilience in relation to socioecological issues is that of the isolation to other worldviews or neglecting perspectives of outsiders, creating cultural ghettos, without communication with mainstream or hegemonic discourses. The idea of STEM4S projects intends to create dialogue and collect perspectives on socioecological challenges both from local and outsider perspectives. Here, the connection with the university and mainstream sciences is key to articulating a broad view of the situation and allowing the analysis of challenges from different perspectives. Nevertheless, this is always a risk, and it is important to raise alarms here of not falling into essentialism or stereotypes of the local or indigenous perspectives.

On the other hand, more specific measurements on attitudinal changes and scientific literacy could also be a great input to this field. It is hard to find research connecting science-based or STEM education with socioecological resilience. More accurate and diverse forms of measuring the impact of these kinds of projects are needed to reach a greater audience and provide solid evidence to foster policy guidelines in this direction. For example, the recent international discussion about the importance of developing inductive scientific thinking, problem-solving skills, and contextualized learning, is directly connected with the results provided here [35]. New mixed-methods approaches that incorporate standardized measures of the mentioned skills would be an interesting next step to explore for future research.

In this sense, this article is an invitation to teachers, educational practitioners, academics, policymakers, and the general public to collaborate with schools and to find opportunities to build socioecological resilience in their areas of influence through meaningful educational experiences. At the same time, school teams have the chance to find local support to also internally rebuild their implemented curriculum, without the need to completely break with current basic topics and the objectives generally imposed. Still, it has some risk of functional compliance with mainstream or dominant epistemologies; nevertheless, with solid arguments and after learning of other experiences such as those collected in this article, it can open minds toward a new way of understanding what knowledge is, and what the role of the school is in its construction.

In terms of practical implications, this article provided a wide range of topics and research questions to explore sustainability issues from an early stage in new contexts. It also gave an idea of possible collaborators, local actors, and types of organizations that might be available to collaborate with schools in other contexts. Moreover, it opens possibilities for new teachers all over the globe to be aware and anticipate possible challenges when implementing STEM4S projects, such as curricular anxiety, internal leadership, and the complications described associated with the fieldwork and data analysis.

This initiative has proven that project-based learning when applied to local challenges and open to new sources of knowledge can achieve an effective way for a positive reframe of teachers' mindsets and attitudinal change, giving a sense of purpose and hope for the future that are difficult to achieve with ways of learning based on the transmission of knowledge. In this sense, the reach of this article transcends the local interest since it opens the possibility to implement similar locally relevant initiatives the world over; it provides a frame to create new projects based on local knowledge and provides guidelines for effective and applicable practice in the initiation and introduction of children into communities of real sustainability.

Finally, when referring to the children that participated in the projects, one of the most valued changes was on how agency toward their local areas grew and on how the sense of purpose of the learning process started to increase. A necessary change toward active, child-centered learning is needed to give a proper active response to the current "doom and gloom" narratives about the future of the planet and to tackle the big emotional challenge of ecological grief with active pedagogies applied to the students' context.

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References

1. Cunsolo, A.; Ellis, N.R. Ecological Grief as a Mental Health Response to Climate Change-Related Loss. *Nat. Clim. Chang.* **2018**, *8*, 275–281. [CrossRef]
2. Clayton, S.; Manning, C.; College, M.; Krygsman, K.; Speiser, M.; Cunsolo, A.; Derr, V.; Doherty, T.; Fery, P.; Haase, E.; et al. Health and Our Changing Planet: Impacts, Implications, and Guidance. 2017. Available online: https://www.apa.org/news/press/releases/2017/03/mental-health-climate.pdf (accessed on 21 July 2021).
3. Pahnke, J.; O'Donell, C.; Bascopé, M. Using Science to Do Social Good: STEM Education for Sustainable Development. In Proceedings of the Position Paper Developed in Preparation for the Second "International Dialogue on STEM Education" (IDoS), Haus der Kleinen Forscher, Berlin, Germany, 5 December 2019.
4. Blanchard, K.; Gibson, H.; O'Donnell, C. Understanding yourself as a foundation for exploring the world. In *NISSEM Global Briefs: Education for the Social, the Sustainable and the Emotional*; Smart, A., Sinclair, M., Benavot, A., Bernard, J., Chabbott, C., Russell, G., Williams, J., Eds.; NISSEM (OECD): Paris, France, 2019.
5. Hirst, N. Education for Sustainability within Early Childhood Studies: Collaboration and Inquiry through Projects with Children. *Education 3-13* **2019**, *47*, 233–246. [CrossRef]

6. Davis, J. Revealing the Research 'Hole' of Early Childhood Education for Sustainability: A Preliminary Survey of the Literature. *Environ. Educ. Res.* **2009**, *15*, 227–241. [CrossRef]
7. Tolppanen, S.; Aksela, M. Identifying and Addressing Students' Questions on Climate Change. *J. Environ. Educ.* **2018**, *49*, 375–389. [CrossRef]
8. Bascope, M.; Reiss, K.; Cortés, J.; Gutierrez, P. Implementation of Culturally Relevant Science-Based Projects in Preschools and Primary Schools: From Roots to Wings. In *Handbook of Research on Environmental Education Strategies for Addressing Climate Change and Sustainability*; IGI Global: Hershey, PA, USA, 2021; pp. 22–38.
9. Cornell, S.; Berkhout, F.; Tuinstra, W.; Tàbara, J.D.; Jäger, J.; Chabay, I.; de Wit, B.; Langlais, R.; Mills, D.; Moll, P.; et al. Opening up Knowledge Systems for Better Responses to Global Environmental Change. *Environ. Sci. Policy* **2013**, *28*, 60–70. [CrossRef]
10. Ferreira, J.-A.; Ryan, L.; Tilbury, D. *Whole-School Approaches to Sustainability: A Review of Models for Professional Development in Pre-Service Teacher Education*; Australian Government Department of the Environment and Heritage: Canberra, Australia, 2006.
11. Müller, U.; Lude, A.; Hancock, D.R. Leading Schools towards Sustainability. Fields of Action and Management Strategies for Principals. *Sustainability* **2020**, *12*, 3031. [CrossRef]
12. Kharrazi, A.; Kudo, S.; Allasiw, D. Addressing Misconceptions to the Concept of Resilience in Environmental Education. *Sustainability* **2018**, *10*, 4682. [CrossRef]
13. Krasny, M.E.; Tidball, K.G. Applying a Resilience Systems Framework to Urban Environmental Education. *Environ. Educ. Res.* **2009**, *15*, 465–482. [CrossRef]
14. Chawla, L.; Keena, K.; Pevec, I.; Stanley, E. Green Schoolyards as Havens from Stress and Resources for Resilience in Childhood and Adolescence. *Health Place* **2014**, *28*, 1–13. [CrossRef] [PubMed]
15. Cretney, R. Resilience for Whom? Emerging Critical Geographies of Socio-Ecological Resilience. *Geogr. Compass* **2014**, *8*, 627–640. [CrossRef]
16. Breton, M. Neighborhood Resiliency. *J. Community Pract.* **2001**, *9*, 21–36. [CrossRef]
17. Clauss-Ehlers, C.S.; Levi, L.L. Violence and Community, Terms in Conflict: An Ecological Approach to Resilience. *J. Soc. Distress Homeless* **2002**, *11*, 265–278. [CrossRef]
18. Putnam, R.D. *Making Democracy Work: Civic Traditions in Modern Italy*; Princeton University Press: Princeton, NJ, USA, 1993.
19. Kawachi, I.; Berkman, L. Social Cohesion, Social Capital, and Health. *Soc. Epidemiol.* **2000**, *174*, 290–319.
20. Kawachi, I.; Berkman, L.F. Social Ties and Mental Health. *J. Urban Health* **2001**, *78*, 458–467. [CrossRef] [PubMed]
21. Sato, T.; Chabay, I.; Helgeson, J. (Eds.) *Transformations of Social-Ecological Systems: Studies in Co-Creating Integrated Knowledge Toward Sustainable Futures*; Ecological Research Monographs; Springer: Singapore, 2018; ISBN 9789811323263.
22. Rozzi, R. Biocultural Ethics: From Biocultural Homogenization toward Biocultural Conservation. In *Linking Ecology and Ethics for a Changing World: Values, Philosophy, and Action*; Rozzi, R., Pickett, S.T.A., Palmer, C., Armesto, J.J., Callicott, J.B., Eds.; Ecology and Ethics; Springer: Dordrecht, The Netherlands, 2013; pp. 9–32. ISBN 978-94-007-7470-4.
23. King, L.; Schielmann, S. *El Reto de La Educación Indígena: Experiencias y Perspectivas*; UNESCO: Paris, France, 2004.
24. Llanquinao Trabol, H. *Los Valores de La Educación Tradicional Mapuche: Posibles Contribuciones al Sistema Educativo Chileno*; Universitat de Barcelona: Barcelona, Spain, 2009.
25. Quintriqueo Millán, S.; Torres Cuevas, H. Distancia entre el conocimiento mapuche y el conocimiento escolar en contexto mapuche. *Rev. Electrón. Investig. Educ.* **2012**, *14*, 16–33.
26. Quilaqueo, D.; Fernández, C.A.; Quintriqueo, S. *Interculturalidad En Contexto Mapuche*; EDUCO-Editorial de la Universidad Nacional del Comahue: Neuquén, Argentina, 2010.
27. Ibáñez-Salgado, N. La Diversidad En La Construcción de Mundo de Niños y Niñas de Dos Culturas. *Rev. Latinoam. Cienc. Soc. Niñez Juv.* **2015**, *13*, 357–368. [CrossRef]
28. Bascopé, M.; Gutiérrez, P. *Antología sobre Indagación "Enseñanza de la Ciencia en la Educación Básica"*; Innovación en la Enseñanza de la Ciencia A.C. (INNOVEC): Mexico City, Mexico, 2019; pp. 10–25.
29. Luna, L.; Benavides, P.; Gutiérrez, P.; Alchao, M.; Dittborn, A. Aprender Lengua y Cultura Mapuche En La Escuela: Estudio de Caso de La Implementación Del Nuevo Sector de Aprendizaje Lengua Indígena Desde Un Análisis de "Recursos Educativos". *Estud. Pedagógicos* **2014**, *40*, 221–240. [CrossRef]
30. Tiburcio Esteban, C.; Jiménez Naranjo, Y. La Enseñanza Del Tutunakú a Través Del Aprendizaje Situado, Bilingüe y Dialógico. *CPU-e. Rev. Investig. Educ.* **2016**, 121–141. [CrossRef]
31. Sichra, Inge. "Enseñanza de lengua indígena e interculturalidad: ¿entre la realidad y el deseo? Investigación sobre la enseñanza del Quechua en dos colegios particulares en Cochabamba." PROEIB Andes. Available online: http://bvirtual.proeibandes.org/bvirtual/docs/ens_lengua_indigena.pdf (accessed on 21 July 2021).
32. Bascopé, M.; Caniguan, N.I. Propuesta Pedagógica Para La Incorporación de Conocimientos Tradicionales de Ciencias Naturales En Primaria. *Rev. Electrón. Investig. Educ.* **2016**, *18*, 162–175.
33. Saldana, J. *The Qualitative Coding Manual*; Sage Publications Ltd.: Thousand Oaks, CA, USA, 2009.
34. Kirmayer, L.J.; Sehdev, M.; Whitley, R.; Dandeneau, S.F.; Isaac, C. Community Resilience: Models, Metaphors and Measures. *Int. J. Indig. Health* **2009**, *5*, 62–117. [CrossRef]
35. Organisation for Economic Cooperation and Development (OECD). *The Future of Education and Skills: Education 2030*; OECD: Paris, France, 2018.