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Article

Enhancing Sustainability Teaching Competence in Preschool Teacher Education Using Living Labs

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Abstract: Developing sustainability competences is an important endeavor for education, as competence development can be complex and requires appropriate approaches. In the case of preparing future educators, this becomes even more important, because of their multiplier role. The current study presents how a project, based on living-lab methodology, helped preservice preschool teachers, attending a course on sustainability issues, develop sustainability-specific professional action competence. Students collaborated with an organization and a school and were trained to deliver to 6-year-old pupils, activities concerning the protection of sea turtles. The process included reflection, based on a given template. After the intervention, the preservice preschool teachers reflected upon their role and professional performance and discussed how they, benefited from this project. They further analyzed through a group interview, how the Living Lab methodology raised their professional confidence and self-efficacy, and helped them develop content knowledge, pedagogical content knowledge, and a sense of purpose and motivation for teaching about sustainability. Outcomes indicate that participants felt confident and efficacious to teach about sustainability, and developed their content knowledge, pedagogy content knowledge, motivation, and volition due to a strong sense of purpose and responsibility. The overall process facilitated the development of critical thinking, systemic thinking, reflection, and collaboration..

Keywords: Preservice preschool teacher education; Education for sustainable Development; Living labs methodology; ESD-specific professional action competence; ESD competences

1. Introduction

Societal transformation and a shift of peoples' worldviews are needed for sustainability to be achieved. Teachers and educators are crucial change agents and the importance of their role has been repeatedly acknowledged by international organizations, in global strategies and political agendas (Agenda 21, the Millennium Goals, Agenda 2030, Global Action Plan, etc). Consequently, expectations and responsibility for developing competent and committed multipliers [1] are placed upon Teachers' Higher Education for Sustainable Development as one of the most important leverages for sustainability [2]. The questions arising from this fact concern what competences, teachers should acquire to become active agents of change and what is required for these competences to be developed.

Competences are defined as the interaction of knowledge, skills, and attitudes that can be learned and can help an individual cope successfully and responsibly with changing situations [3, 4]. A literature review on the frameworks developed for Sustainability education competences reveals an abundance of models and frameworks [5, 3, 6, 7, 8, 9], with a high degree of convergence on which are the key competences in sustainability. All models coincide that competences are learnt and that to transfer sustainability competences to students, educators should develop these competences too.

In a professional context, competence is defined as the ability to integrate and apply contextually appropriate knowledge, skills, and psychosocial factors (e.g., beliefs, attitudes, values and motivations) to consistently perform successfully within a specified domain [10], (p.4). So, beyond

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sustainability competences what other ESD-specific professional competences do teachers need to effectively integrate sustainability into the teaching and learning process?

In order to acquire ESD-specific Professional Action Competence, preservice teachers are expected to develop content knowledge of sustainability issues, pedagogical content knowledge, and become motivated to apply ESD in their professional practice [11]. Possessing a strong understanding of ESD, along with the ability to integrate ESD principles and practices into their teaching, enhances preservice teachers' self-efficacy. Equipped with ESD-specific competences they are better prepared to engage their pupils in learning about sustainability and foster a classroom environment that supports critical thinking, problem-solving, and active participation in sustainability practices [12].

Research has revealed a series of factors through which Higher Education can support future teachers' learning process for ESD, the most important being, motivation and understanding the value of engaging in the learning process [13]. This entails "deep learning" connected to "social learning", where students interact with and learn from peers, reflect, discuss, and receive feedback and tutoring [4], (p.15). Contexts that create such learning environments were explored by several researchers and highlight the value of case-study approaches, project-based learning, place-based learning, participatory action research, and authentic learning environments [14, 15, 16, 17]. Similarly, Cebrián et al (2019) [18] encourage opportunities for experiential learning and praxis-oriented pedagogies for fostering ESD competences and self-efficacy. A promising approach for Higher Education, providing an authentic learning environment that can enable the development of ESD-specific action competence for preservice teachers is the Living Labs approach. Living Labs incorporate the idea of scaffolding [19] and include partnerships between learners, practitioners, and other parties that facilitate preservice teachers' learning in real professional settings.

The purpose of this study was to examine the learning experiences of a group of university students to become pre-school teachers in the early stages of their studies, who attended an introductory course on sustainability issues. Part of the course's requirements was for the students to collaborate with an environmental organization, receive training, and deliver gamified activities to six-year-old children on the protection of sea turtles, adopting elements of Living Lab methodology. Being in their first and second year of studies, and attending a content course, students were not asked to develop the activities they delivered. (This is planned for their didactics course that comes later on in their studies). The activities were developed and provided by the collaborating organization as part of a large-scale LIFE project. The process included students' receiving training from the collaborating organization concerning the content knowledge and the gamification approach of the activities; reflection on the planned activities following a given template; and reflection on the activities after their delivery to children. On the first template, (before the intervention) students reported that they expected pupils to learn about sea turtles, develop collaboration and communication skills, and competences such as critical thinking and empathy with non-human organizations. On the after-the-intervention template, students confirmed their hypotheses about what they expected children to learn, reflected upon their role and professional performance, and discussed how they, as future preschool teachers, benefited from this project. Through a group interview, they further analysed how the Living Lab methodology raised their professional confidence and self-efficacy, and helped them develop content knowledge, pedagogical content knowledge, and a sense of purpose and motivation for teaching about sustainability.

2. Literature Review

2.1. Preparing Competent Educators

University education turns to competence-based ESD [20] as it is outcome-oriented [21] and can help the professionalization of students - future professionals [22]. Competence-based education is an approach to learning that focuses on the development of specific skills and abilities, rather than just acquiring knowledge. Instead of progress based on traditional grading systems, competence-based education assesses individuals on their mastery of particular skills or competences. In this context, learners progress when they have demonstrated proficiency in the required competences.

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The emphasis is on real-world application and practical skills that are relevant to a person's professional or personal goals.

The term "ESD-specific professional Action Competence for teachers" was used by Bertschi et al (2013) [11] to describe the specialized abilities and knowledge required by primary and pre-primary school teachers to effectively design, implement, and evaluate educational interventions within the context of Education for Sustainable Development (ESD). This competence encompasses not only general teaching skills but also specific ESD-related knowledge, pedagogical approaches, and the ability to foster critical thinking and sustainable actions among students. It aims to prepare teachers to guide students in understanding and engaging with the principles of sustainable development, thereby contributing to a more sustainable future.

Bertschi et al (2013) [11] indicate two competence aspects to the professional action competence for ESD: the aspect of motivation and volition and the aspect of knowledge and ability. The first one, motivation and volition refers to competence components such as acknowledging sustainability as a regulative idea and a challenge for society as a whole; understanding that education can exert leverage for addressing sustainability as a societal task; acknowledging ethical judgment as an educational goal and as a central part of the co-creation competency that students should develop (p. 5076). It entails values and beliefs that are important for teaching about sustainability and includes "value commitments, epistemological beliefs (world views), subjective theories of teaching and learning, and goal systems" [23], (p. 37). Motivation and self-regulation abilities are important determinants of intentions and behavior and are therefore relevant for psychological functioning (ibid). The knowledge and ability aspect refers to components that entail ESD-specific knowledge (content knowledge) and ESD-appropriate pedagogical approaches that teachers need to acquire (pedagogy content knowledge): For example, the ability to choose suitable teaching topics and evaluate; to make ecological, economic, social and cultural perspectives accessible to students using appropriate teaching approaches and activities; to acknowledge conflicts of goals and interests and address them in a pedagogically appropriate and constructive manner; to develop and provide efficient learning opportunities (p. 5076). According to the model proposed by Baumer and Kunder (2013) [23], competence development is facilitated through a context that ensures amongst others, practical relevance for the planning; implementation, and evaluation of ESD teaching; the ability to be contextualized in a theoretical framework; and discussion of teachability and learnability of the described outcomes. The model of pedagogical action competence is characterized as a model that reflects a rather narrow understanding of competence, as it is conceptualized as profession-specific (i.e., specific for schoolteachers) and domain-specific (i.e., PE, science or ESD) [24] (p. 4).

Focusing on the development of sustainability competences and professional action competences during university studies can effectively raise pre-service teachers' self-efficacy and confidence in their competence to deliver ESD to their students. Pre-service teachers' self-efficacy in Sustainability Education significantly affects their ability to teach about sustainability in class. A study by Karvonen, Ratinen & Kemi (2023) [24] found that self-efficacy beliefs, particularly in teaching values, ethics, and systems-thinking, are crucial for enhancing pre-service teachers' sustainability competency. The study emphasized the interconnectedness of self-efficacy beliefs and sustainability competency, advocating for a focused approach in teacher education that addresses both these aspects.

The development of pre-professional identity in undergraduates through Work-Integrated Learning also plays a crucial role in the professionalization of university students and effectively prepares them for their future professional roles. Professional confidence and self-efficacy are found to be connected to the development of a pre-professional identity in undergraduates through work-integrated learning which contributes to the students' professionalization. The process of developing pre-professional identity includes the immersion of students into real-world professional environments, which enhances their understanding of professional standards, expectations, attitudes, beliefs, and ethical values associated with their chosen professions. This authentic learning experience, facilitated by work placements, allows students to gain firsthand insight into professional practices and ideologies, which is instrumental in shaping their professional identity. It equips

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students with professional skills, knowledge and attitudes; encourages them to be inquisitive, challenge established practices; be critical about their workplace experiences and practices; it helps them build a network of professional collaborators; and builds their confidence in their ability to enter and succeed in their chosen professions [26]. An important aspect of this process is reflection and feedback within the work-integrated learning experience of the student. Reflecting on performance and receiving constructive feedback is fundamental for students to improve their practice and align it with professional standards. Further, Jackson (2017) [25] discusses that by developing a pre-professional identity, students will gain a clear understanding of and connection with the core values, expectations, motivation, and behavior central to their future practice (p. 835).

2.2. Appropriate Contexts for Professional Action Competence Development – The LIVING Labs Methodology

As presented in the introduction, appropriate learning environments that can promote deep learning, support pre-service teachers' learning for ESD, and build their motivation and professional action competence for sustainability, include case-study approaches, project-based learning, place-based learning, participatory action research, praxis-oriented pedagogies, and authentic learning environments [14, 15, 16, 17, 18]. This article focuses on the Living Lab methodology, as a promising approach, that provides an authentic project-based learning environment that can enable the development of ESD-specific action competence to pre-service teachers through work-integrated learning.

Living labs can be defined as the "sites in which experiential learning takes place not in a controlled and managed environment, …, but rather in social contexts of complex, dynamic institutions whose problems and challenges cannot be treated in isolation" [27], (p.96). Della Santa, Tagliazucchi and Marchi (2022) [27] define Living Labs as "innovation ecosystems that integrate research and innovation processes in a real-life setting, in a logic of open–user innovation". The second definition proposes that the concept of Living Labs is not exclusively understood as physical spaces, (e.g. campus as a living lab), but also entails the concept of a living lab as a framework of learning.

For the needs of this article, the concept of Living Labs is understood as a framework of learning and we adapt the definition given by the SALL project: "Living lab is an open-innovation methodology where people participate horizontally in an innovation process to co-create solutions to real problems. In education, living labs are places where students, schools, citizens, and organisations come together to co-create (ideas and tools)" [28], (p.2).

All definitions provided above highlight the real-life setting as a key element of living lab operation that defines the space where the innovation process takes place. The element of real life is set by the authenticity of the issue that will be addressed by the living lab; the collaboration network that will be established between learners, the university, organisations, and other parties; and the real action for finding a solution to a real problem or meeting an existing need of the organization or other partners.

As a methodology, living labs include steps that take learners through a preparatory phase (step 1) during which students are presented with the specific problem – challenge, with the help and guidance of their academic teachers, the collaborating organizations, and other parties. In step 2 students form groups and work together to identify sub-topics on which their group could work, or could be assigned similar or different aspects of the topic, depending on what the project is about and what is needed to be done. Groups work on a proposed solution and present their ideas to the interested parties for feedback before finalizing their plan of action (step 3). Step 4 concerns implementation and action and step 5, a final reflection and evaluation of the overall outcome and experience. The process is flexible and the difficulty level depends on students' academic and practical experience. Living lab projects engaging university students in their initial years of study, can be less demanding and be more structured to provide sufficient support and ensure a successful positive experience. In the case of pre-service teachers, the living lab context can provide experiences beyond the formal teaching practice by engaging students in informal education projects and

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processes in collaboration with schools and organisations. These experiences are supportive of their professionalization and the development of their pre-professional identity as they can challenge traditional practice, help them gain a different angle of view to formal educational settings, and encourage them to try out innovative approaches and contexts. This is important, given that the traditional teaching practice provides an experience that reproduces a norm that in some cases should not be reproduced.

3. Materials and Methods

The purpose of this study is to explore the value of the living lab's authentic learning context in terms of ESD-specific professional Action Competence for teachers. More specifically, we will try to identify (a) if and how the Living Lab's authentic learning context, has helped pre-school teacher-students develop content knowledge, pedagogical content knowledge, and a sense of purpose and motivation for teaching about sustainability, (b) which sustainability competences were developed and (c) what impact the living lab methodology had on their self-efficacy and confidence.

3.1. Participants

The participants in this study were sixteen preschool university students (14 on their first and 2 on their second year of studies), attending an introductory course on sustainability issues. Students were between 19-23 years old and all of them were female, something that is common in pre-school educational studies. The course they attended includes activities that expose students to real-life sustainability issues (e.g. through visits to Environmental Education Centers) and other participative activities. For this study, students were immersed in a real professional experience, in collaboration with an environmental organization, and a school. The experience was highly structured, considering that the students were inexperienced and had not attended the sustainability pedagogy course yet.

3.2. Procedures

The collaborating organization, as part of a broad-scale research project, developed a series of gamified activities, to raise public awareness of the dangers that threaten turtles in our island. The activities were developed by the researchers and addressed children from kindergarten ages up to the final years of primary education. The collaborating organization was seeking volunteers to deliver the activities to children, and if possible, educators-volunteers who could provide feedback on the age-appropriateness and effectiveness of the activities as part of an action research process. Similarly, our university was seeking opportunities, to expose students to innovative professional experiences beyond teaching practice.

The procedure followed, was aligned to steps undertaken within a living-lab methodology (see Figure 1):

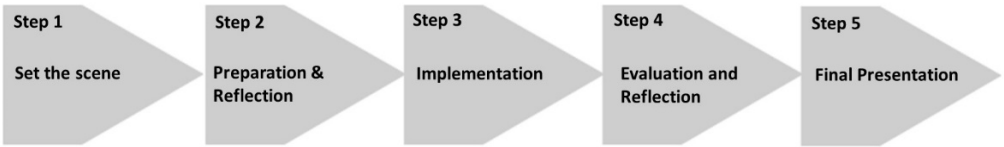

Figure 1. The Living Lab steps followed**.**

Step 1. The collaborating organization delivered a 2-hour training to the students concerning the theoretical background preservice teachers needed to have about the sea turtles and the activities they would be invited to deliver. Gamified activities included board games; a simulation game using a life-size sea turtle model, plastic eggs, and nest protection equipment; a puzzle game that once completed would illustrate the life-cycle of the turtles, matching games about turtles' dietary habits, etc. At the same time, the course instructor contacted a local neighboring primary school (proximity convenience) and arranged for the students to visit the school and deliver the activities to the first-year pupils, during the first trimester of the school year. At this time of the year, grade one children

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are still transitioning from pre-school and they were an appropriate group for the pre-school university students to work with.

Step 2. Students worked in groups to thoroughly study the given material and the activities. As one of the objectives was to provide the collaborative organization with feedback about the activities, students were asked to fill out a reflection template on their expectations regarding the activities and their impact on children before the intervention at the school. This task was intended to engage students in a deeper and more critical study of the activities and the material given, so as to be well prepared for the delivery.

Step 3. The following step concerned the school visit and delivery of the activities. The games were set in six stations. Five groups of 3-4 university students were responsible for five groups of approximately 6-8 children in each group. The activities were delivered once for the first half and a second time for the rest of the 1st-grade pupils. University students had to present, explain, coordinate, and manage the activities, the transition of the children from one activity to the next, and resolve any issues that might arise.

Step 4. Returning to the university, students had to fill out a second reflection template, now with their actual observations and comments on their experience. As part of the living lab endeavor, students' groups discussed and delivered their report on the suitability of the activities delivered and prepared a powerpoint presentation within which they presented and analysed comments and suggestions for the improvement of the activities.

Step 5. The final part of the project included the last visit of the organization, during which the groups of university students presented their suggestions.

3.3. Data collection

Students were informed of the living lab methodology project they would engage in during the semester, and they consented to provide data that would help the instructor improve the experience for future students. They were ensured that any contribution to the research data would remain anonymous and would be disconnected from their grade in the course. Data were obtained from the reflection templates filled before and after the delivery of the activities, observation of the recorded presentations of the students as professionals to the collaborating organization, and finally an informal group interview with some of the students attending the course at the end of the semester. During the interview students discussed their experience with the living lab project and reported on professional and sustainability competences they developed, their confidence in their ability to teach, and the ways they worked as a group.

3.4. Analysis

Data were obtained through qualitative, self-reporting processes and described preservice teachers' empirical experience of the living lab project. The reflection sheets were reviewed to identify indications of the development of sustainability and professional competences, as discussed in the introduction. The group interview was analysed following a qualitative process, of coding themes and proceeding with thematic analysis and reporting.

4. Results

The outcomes presentation is organized according to the research questions addressed within this article.

4.1. Development of Professional Action Competence for Sustainability Education

4.1.1. Content Knowledge

Through the reflection sheets and during the group interview students reported that they studied and learned important facts about sea turtles. To perform the given activities they had to learn about the life cycle of the turtle, its eating habits, the parts of its body, the dangers the turtles face in the sea and on the shore, etc. Characteristically, one of the pre-service teachers mentioned

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during the interview: "…There was information that we did not know, for example, what the turtles eat. So we were better prepared about what we had to explain to the children or the threats that turtles face. Some of us did not know about how lights affect the newborn turtles' orientation and that baby turtles mistake them for the moon, which would help them understand to which direction they have to go to find the water…" (Student 7).

4.1.2. Pedagogical Content Knowledge

The several steps that were followed before the actual school intervention, appeared to help students better prepare and understand the pedagogy they would have to apply. During the group interview Student 2, mentioned "…the steps we followed before going to the school, were very helpful because they helped us understand what was expected by us, what we were going to do with the children, what we were going to say". She further analyzed that the steps (the training provided by the collaborating organization, the fact that they had to study the information about the turtles, and the description of the activities in order to fill in the initial group reflection handout), "…made us consider what can trigger the children's interest, what they can learn from each activity, what can keep them engaged? All these considerations and hypotheses were later on proved to be right […] because they were accounted for. Overall we got better prepared and tried to predict any obstacles or situations that might arise and consider how we could address them before they even happened".

The experience with the children also was reported as important for their pedagogical content knowledge: "We better understood what we had to do. We were in front of children. We had to guide them through all the activities, from the beginning to the end... We couldn't go there without knowing what we would do or say. It would be unacceptable to give them inaccurate or erroneous information" (Student 3). Addressing real children was also helpful with classroom management skills: "We tried to have all children participate at least once in the activity …" (Student 2).

Preservice teachers commented that the process did not provide opportunities for receiving feedback, as the activities were pre-designed. The fact that they were given ready-made activities was intentional, as most of them were just beginning their studies and the process should not be excessively demanding and intimidating for them.

4.1.3. Motivation and volition

The sense of purpose and responsibility created within the context of the living lab project developed motivation and volition to the students. Student 1 explained that: "the things [responsibility and awareness about turtles] that we considered about ourselves, the need for more responsible conduct… we felt that it was important to also transfer to the children. We felt the necessity to transfer this to the children and help them think in the same way we started to think".

4.2. Developing Sustainability Teaching Competences

Several competences were mentioned within both the reflection handouts filled out by the Pre-Service teachers as well as the group interview at the end of the course. Most participants highlighted collaboration as the competence that stood out. They extensively elaborated that the living lab context created not only an authentic experience but also an authentic collaboration among them. Student 2 commented, "I think we were a very good group, we prepared thoroughly for the delivery of the activities, and we helped each other". To prompt deeper into this observation, and identify the reasons why the collaboration experience was so intense in the preservice teachers' minds, they were asked whether collaboration, in this case, was better compared to other collaboration opportunities they had and invited to explain how the living lab project was different to other group projects they had to implement. Their answers revealed that a sense of responsibility motivated them to work differently: "…because, of what we had to do afterward in the school, the practical part with the children, was something that we would deliver in person. We were the teachers at that moment. When we do a conventional assignment for the university, collaboration could mean, one does one

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part, the other one does something else… In the case of this project, we distributed work but shared responsibility. We all were engaged in all the stages and processes. At the school all three of us had activities to do, we had previously decided who would lead which activity, and each of us had thoroughly studied the ones she was responsible for, but we also carefully went through the other activities, so that we would all be ready for all the activities, just in case. We wanted to be well prepared in case a member of our group needed support, and indeed this happened. While I was leading one of the activities I needed help and Eleni jumped in, or at another moment I intervened to help Student 6… anyone who could step in and help did so. We felt the responsibility and this was a strong motive for good collaboration, perhaps because children were involved" (Student 1). Student 2 provided a similar comment: "We had shared the responsibility of the activities, but at that moment, in practice, we all helped. For example, if I was explaining the activity and one of the children was distracted, Student 4 would draw his attention to me. Our peers, who did not have the leading part during an activity, kept an eye on the children or everything that the activity leader might need really, so as to make sure that all would be delivered well".

Pre-service teachers also mentioned that their awareness was raised and that the things they learned "…made us think more responsibly when we go to a beach for example. A small litter that we may consider insignificant, can be a significant threat to sea animals…" (Student 1). They also mentioned feeling empathy with non-human beings and compassion for the turtles and commented that they started making connections. They could now understand how "…for example, the fact that some people litter the beach may lead to the death of a sea animal" and acknowledge this as a systemic way of thinking "This is systemic thinking because we make the connections right?" (Student 2). Student 1 expanded on systemic thinking: "…If you think in this way and seek causes and consequences, and you use the same way of thinking, making connections, in other contexts and considering other things, you can conclude that there may be several things we do not see, or we are not aware of, but one brings the other. So, this project and its context did help us see these connections".

Reflection was considered important, although pre-service teachers did not consider it to be a competence but part of a critical and creative thinking process. Some students found reflection induced during the group interview, as an informal group discussion "very helpful, because, your questions guide our reflection in many aspects... when we talk I can have more ideas and arguments. In front of a screen, I may get stuck and not know what to answer. So, this interaction is more constructive" (Student 1). Others felt that reflection sheets gave them more time to think: "…I think I prefer written tasks of reflection. I have more time to consider everything and to remember children's questions and reactions. I was impressed by how many things they would tell me about themselves, about what they do at home, about recycling, a little girl told me about when she went beach cleaning with her family" (Student 2). Student 4 found both useful "…I think both are useful. Perhaps the oral discussion first to help us recall things and interact and the written to follow".

Student 4 commented that the project experience made her think critically. She understood critical thinking as "To be able to think and process information. Further on, developing critical thinking will make us better (teachers)" and Student 1 expanded on this comment mentioning that critical thinking is actually what made them feel the need to act more responsibly: "Yes, but if you start thinking, elaborating and considering some things and finally realize that your actions may have a negative impact, for example throwing garbage in the beach may lead to the death of an animal. This is an irresponsible behavior. This is what I mean by critical thinking leading to a more responsible way of acting and behaving. It also can make you think about things you did in the past. Although these you cannot change, at least you will make sure not to repeat them in the future".

In their reflection handouts, preservice teachers also commented that they observed similar skills and competences being developed by children. Student 6 mentioned that "…while learning about sea turtles, children developed skills in communication, collaboration, critical thinking, and empathy". The same skills were mentioned by several of her peers, within their reflection sheets.

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4.3. The Living Lab Process and Preservice Preschool Teachers' Self-Efficacy and Confidence

The prospect of actually teaching children was stressful for preservice teachers. This was expected considering that they had little to no previous teaching experience. They admitted that "…it was a huge responsibility. At first, I was shocked and really worried… but in the end, we did well and I am very happy about it [laughing]" (Student 2). They also pointed out that "…on top of everything you didn't know the children and their particularities. Would they behave or would we have a problem keeping their attention, would they listen or would they do whatever they wanted? This was stressful. When the children came to the activities area and we saw the groups of pupils, we felt more assured because they were calm children with whom we could work" (Student 1).

Working in groups and peer support, ensured that the experience was not an intimidating one. Student 3 admitted: "Yes, I had to teach … the kids without having someone telling me what to do. I was responsible. I mean, I was alone, with a group of pupils and my fellow university students, we did not have our instructor by our side most of the time, or any of the school's teachers. Nobody would tell me how to answer a question or what to do, I was in control".

Being well prepared also ensured that pre-service teachers would be successful in the implementation part. As Student 2 commented: "…I did not expect to have such good communication [with children] and work so well with them… because they are older [than pre-school children] and perhaps not so disciplined. My group had very good communication with the 6-year-old pupils assigned to us…". Student 1 also explained that "… I felt very well, and confident because I was successful. I felt that I was ok. I left home in the morning to go to school, having set some goals, basic goals: to be able to explain to the children the activities, and deliver them correctly. In the end, I felt that I did very well indeed. For example, in the Monopoly-style game, my group was probably the only group that managed to finish the game and the children were very happy about it. So even though the time we had was limited, it was a great first experience with teaching about an environmental issue".

As an overall experience, preservice teachers commented that their interaction with the pupils helped them overcome any doubts, insecurity, and reservations they had: "…In general, I am an introvert. I do not talk much. I normally just sit on my chair and attend… this [activity] helped me, … overcome my worry about saying something wrong. I had studied but I still felt this insecure..." (Student 7). "I easily feel stressed if I have to talk in front of others. It helped that we had to do with children. It developed my confidence. It also helped that we were a group. We did not feel alone. I could count on my fellow students to support me if I did something wrong and this eased my anxiety and made me feel safe" (Student 4). They found the project "very creative and interesting project, more than other assignments we have to do for our university courses... It was useful and fun, perhaps it was the fact that it was based on playing, it was the connection and interaction with the children… It is one thing to be given a topic to do an assignment, and another to work as a real team, to go to a school, play and interact with the children" (Student 2).

In the reflective handouts, most of the preservice teachers expressed satisfaction and enjoyment from their authentic professional experience, indicating that the project was not only educational but also engaging and rewarding: "…the experience was enjoyable and original, providing a positive first interaction with children..." (Student 5). They felt rewarded for the outcome and were "satisfied because we could see children leaving happily and with increased knowledge about turtles. The children also became sensitized about protecting turtles, which was particularly pleasing...," (Student 8)

Overall the responses were overwhelmingly positive, reflecting a sense of accomplishment and satisfaction with the educational outcomes. This positivity is important for maintaining motivation and a sense of purpose in educational endeavors.

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5. Discussion

5.1. Development of Students' Professional Action Competence for Sustainability Education

Although the literature lacks a consensus on what are the most important elements of Professional action competence for sustainability Education [29], Lochmann et al (2021) [24] identify among researchers, a convergence in Content knowledge; Pedagogical Content knowledge; beliefs and values and motivational orientations. In this study, there is empirical evidence to support that preschool teachers developed to some degree all three elements.

5.1.1. Content Knowledge

Content knowledge is crucial for teaching. It enables teachers to acquire a deep understanding of the concepts they are expected to teach, which is fundamental for designing and delivering instruction effectively. A deep understanding allows teachers to anticipate any misconceptions, prepare clear and accurate explanations, and adapt teaching strategies to meet the diverse needs of their students [30]. Participants in this study stressed how important it was for them to go through the background knowledge and the description of the activities to foresee any obstacles and be proactive. They reported developing content-specific knowledge to be able to deliver the planned activities to children. Content knowledge is also found to help teachers develop students' problem-solving skills and critical thinking, by presenting challenging and meaningful learning opportunities (ibid). A study by Norton (2019) [31], also reports that pre-service teachers with higher levels of content knowledge tend to demonstrate a higher level of confidence and self-efficacy in their ability to teach. The relationship between content knowledge and self-efficacy, underlines the importance of the former as a foundation for effective teaching, as it builds teachers' confidence and perceived competence in their abilities to facilitate student learning.

For the case of sustainability education, Brandt, Barth, Hale & Merritt (2021) [1] argue that sustainability content knowledge in preservice teachers' education is crucial and should form a foundational aspect of their university education. A solid understanding of sustainability concepts and content is a prerequisite for preparing future educators to effectively integrate sustainability into their teaching practices and contribute therefore to the broader goal of fostering sustainable development through education. Pre-service teachers in this study appreciated the content knowledge they developed through the project, considered the experience positive, and demonstrated a positive disposition to teach sustainability issues. Richardson, Byrne, and Liang (2018) [32] discuss how content knowledge enhances students' pedagogical content knowledge, teaching efficacy beliefs, and confidence in sustainability education. Their study showcases how targeted educational interventions, (e.g. development of instructional materials, collaborative learning experiences that foster a community of practice, and reflective assignments) provide theoretical knowledge and practical application opportunities, emphasize active learning, collaboration, and reflection, and can significantly improve pre-service teachers' teaching efficacy in sustainability (ibid).

5.1.2. Pedagogical Content Knowledge:

Pedagogical Content Knowledge is described as the specialized knowledge that teachers possess to deliver subject matter to learners through teaching, considering possible misconceptions and learning difficulties students might have [33, 34]. This knowledge is identified as a unique blend of content and pedagogy that belongs specifically to teachers and is imperative for the effectiveness of teaching. Pedagogical content knowledge is developed through a combination of theoretical knowledge and practical experience, emphasizing the importance of understanding content in ways that make it comprehensible to students.

The evolution of pedagogical content knowledge is a dynamic construct and involves reflective practice, engagement in professional learning communities, and targeted activities designed to integrate content knowledge with pedagogy [35]. Although there is no measurable evidence of participants' developing pedagogical content knowledge in this study, the outcomes indicate that

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several of the requirements for its development are met. Group work, collaboration, and peer support established a sense of community, reflection was part of the process and the experience provided insights into effective teaching strategies, bridging the gap between theory and practice (ibid). The process followed in the framework of the living lab methodology, had a scaffolding effect on preservice students and they had the opportunity to reflect on the pedagogical approaches used and their effectiveness on children.

5.1.3. Motivation and Volition:

The living lab methodology supports the development of students' motivation and volition by actively engaging them in sustainability initiatives, fostering experiential learning, and providing hands-on experiences that link academic knowledge to civic responsibility and positive social change [36,37]. This perfectly reflects the example presented in this study. Students were involved in a sustainability initiative responding to civic responsibility and action for change, as the objective was to raise awareness on the protection of a local endangered species; students followed experiential learning and hands-on processes, and they gained professional experiences linked to academic learning. The overall Living lab experience helped students shape their learning journeys, engage deeply with the content, and take responsibility for their educational outcomes [39]. As reported by the study's participants, they were mostly motivated by their professional responsibility towards the children and the partner organization, as well as by their raised awareness of the endangered sea turtle.

5.2. Developing Sustainability Teaching Competences

Active learning methodologies offering real-world experiences in higher education sustainability education can foster the acquisition of sustainability competences to promote the 2030 Agenda for sustainable development goals [39].

In the context of the living lab methodology followed in this study, developing specific content knowledge about turtles helped pre-service teachers better understand systems and their dynamics. They reported how simple unsustainable actions, which they considered to be insignificant, they now understand that can have systemic impact and unpredictable consequences. Grasping the interconnectedness of ecological, social, and economic systems to foster sustainable development effectively enables educators to teach sustainability concepts more comprehensively, helping their students recognize the impact of human activities on the environment and the importance of sustainable practices.

Fanta, Braeutigam, & Riess (2019) [40] consider the integration of systems thinking competence in teacher education as one "mosaic stone in the process of developing awareness and fostering critical thinking about sustainably". The authors (ibid) encourage fostering and teaching systems thinking, becoming part of the teacher education curricula, especially in ESD-related topics. Indeed students, being able to establish the connections between actions and outcomes realized the devastating consequences of specific actions, viewed these actions through a new critical lens, and considered that this critical thinking led them to awareness raising. Critical thinking is described as the ability to question norms, practices, and opinions; to reflect on one's values, perceptions, and actions; and to take a position in the sustainability discourse. It leads to an increased self-awareness competency, which involves reflecting on one's role in the local community and global society, continually evaluating and further motivating one's actions, and dealing with one's feelings and desires [41]. These competencies directly suggest that critical thinking and self-awareness not only increase students' motivation and volition towards sustainability but also enhance their ability to engage critically with sustainability issues, thereby fostering a deeper understanding and commitment to sustainable development goals and a positive disposition for action.

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5.3. The Living Lab Process and Preservice Preschool Teachers' Self-Efficacy and Confidence

Mastery experiences are the most powerful source that can contribute to preservice teachers' self-efficacy [42]. Therefore, it is important to offer ample opportunities for mastery experiences to preservice teachers. These can include hands-on teaching opportunities (for example teaching an individual child, or a small group to an entire class), vicarious experiences, and verbal encouragement and support from educators and cooperating teachers [43], (p.34). The living lab methodology is a context within which preservice teachers can acquire mastery experiences through real teaching. Participants in this study had very limited to no previous teaching experience, and expressed their lack of confidence and stress with the prospective activity. The several steps of the living lab methodology, as well as the peer collaboration, ensured enough guidance and support at every stage of the process, which gradually built their self-efficacy. The successful outcome, as explained, boosted their confidence.

The living lab experience also helped them construct a better understanding of what being an effective teacher means. They experienced educational praxis, in a context beyond formal education. The opportunity to assist the collaborating environmental organization with the action research process of a project, allowed the students to experience a non-formal education perspective complementing formal education. Non-formal education elements that surpass the norm and the traditional practice, can promote innovation and encourage the positive change required within the context of sustainability education. Such learning experiences can create conditions for constructive challenge and questioning of traditional practice, that will help preservice teachers gain a clearer understanding of "professional standards, expectations, ethical values, ideology and conduct to frame one's behavior and professional stance" [25], (p. 834).

6. Conclusions

The findings suggest that targeted, authentic educational experiences, such as those provided by living labs, can significantly contribute to the development of professional action competence for sustainability education, encompassing knowledge, competences, and motivation, necessary for teaching sustainability concepts effectively. Participants reported increased professional confidence, self-efficacy, and a strong sense of purpose, indicating the effectiveness of experiential learning environments in fostering essential competencies for future educators.

This empirical study engaged a small group of preservice preprimary students. We acknowledge a need for broader evidence to generalize the outcomes, and exploration of additional factors influencing teacher self-efficacy and the development of ESD specific professional action competence. A limitation to this study is also the fact that preservice teachers were given, ready-made activities/games to implement. Although this was a conscious decision, taken to make the experience structured, easier and supportive for the inexperienced pre-service preschool teachers, it also deprived them of the opportunity to create the activities and receive constructive interaction, feedback, and guidance from their tutor or the other collaborators in the project. For preservice teachers, planning what they will implement is an important element for their teaching competence development [23]. Nonetheless, the simplified, and structured process followed, ensured a positive first experience, positive attitudes development, and paved the way for similar but more demanding endeavors.

Future research directions could include a more demanding framework of a living lab, including not only the delivery but also the development of educational interventions by the preservice teachers. It could also include the integration of similar approaches across different educational contexts and disciplines to enhance teacher preparedness for addressing sustainability and other complex global challenges.

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