Preservice Teachers’ Meaningful Science Learning

A Collaborative Project Between a College of Education and an Elementary School

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This article describes how preservice elementary teachers learn about the nature of science and develop scientific literacy through a collaborative project that prepares them to design meaningful learning experiences for students. The Life’s Replica Project was an effort between a college professor and an elementary school teacher to facilitate meaningful science learning. The preservice teachers were students from two college courses in a teacher preparation program. The project’s strategy focused on learning through problematization and inquiry-based activities that engaged participants in diverse and collaborative learner-centered experiences. Students were presented with the problem of human beings’ impact on Earth’s ecosystems, and they were challenged to collaborate through community service by creating and presenting a product that addressed the needs they identified. Some of the project’s assessments were the answers gathered in the KWH table (know, want to know, and how will we learn it), from group reflections on the learning experiences with the core activities of the project, and through the creation of educational materials. The project’s assessment outcomes demonstrated its contribution to the development of meaningful science learning for preservice elementary teachers.

As stated in A Framework for K–12 Science Education (National Research Council, 2012) and the Next Generation Science Standards (NGSS Lead States, 2013), science education should emphasize ideas and practices to, among other goals, ensure that all students understand the nature of science and use scientific knowledge to explain phenomena by the time they finish 12th grade. The nature of science refers to its distinctive characteristics, which govern the way scientists work, influenced by their beliefs and values (Clough, 2006; Lederman, 1992). A person who understands the nature of science should act as a scientifically informed citizen (Lederman & Lederman, 2014). To do so, citizens must possess scientific literacy that allows them to apply scientific knowledge to personal and social issues (Roberts & Bybee, 2014).

Zeidler and Sadler (2011) affirm that scientific literacy also includes values and their application in decision-making. According to Klafki (quoted in Duit et al., 2012), to develop scientific literacy, one must address five questions, two of which refer to the meaning of scientific content (e.g., experiences, knowledge, skills) in the student’s present life as well as in the future. Therefore, it is necessary for students to be able to reflect on their knowledge of the nature of science and the importance of scientific literacy in their lives as individuals, as part of a community, and as citizens of a country. To achieve this goal, students must find meaning in learning science by applying it in real, everyday life.

Teachers have a great responsibility for the development and building of their students’ knowledge (Genç, 2013). Primary-level teachers provide children with their first formal science education, and the elementary grades constitute the foundation for the learning of science at higher levels. It is therefore necessary to strengthen the preparation of elementary-level teachers in the nature of science and scientific literacy as meaningful for daily life.

Research on the preparation of science teachers underscores that a fundamental challenge resides in the prior teaching, learning beliefs, and experiences of those learning to teach (Russell & Martin, 2014). Harlen, quoted in Appleton (2007), identified that many elementary science teachers were relying on the textbook or prescriptive work cards that give children step-by-step instructions, emphasizing expository teaching and underplaying questioning and discussion. Because teachers teach the way they were taught (Blume, 1971), the preparation of preservice elementary teachers should focus on the experiences that develop their knowledge of the nature of science and scientific literacy in ways that make science meaningful and useful for their lives, in turn allowing them the opportunity to facilitate this learning experience for their students.
Meaningful learning

Daily life is full of challenges, problems to solve, projects to complete, and services to provide, all of which can serve as contexts to develop critical thinking and facilitate meaningful learning (Velázquez Rivera et al., 2016). For Velázquez Rivera and Figarella García (2018), meaningful learning occurs when what is learned serves a purpose in real life and is highly valued by the student. In other words, the student understands that such learning is functional in both the present and the future. This understanding requires a vision of learning that recognizes that much of what people know about the world, including knowledge and scientific processes, is built from their experiences with a diversity of real, physical, and social contexts that awaken an intrinsic need to learn naturally, as it stimulates their need for knowledge. Problematization refers to the process of facilitating the creation of cognitive conflicts in students to help them move to higher levels of cognition (e.g., analyze, reflect, investigate, create, act, and evaluate) to construct new learning (Velázquez Rivera & Figarella García, 2018). Developing these high levels of cognition is particularly important for the brains of adolescents and young adults up to age 25 (Spinks, 2002). Generally, preservice teachers are younger than 25 years old, which is one of the main reasons for developing activities that require preservice teachers to think critically, as what happens in teacher preparation classrooms affects teachers’ brain development (McGinnis, 2018). Similarly, what our preservice teachers do once they begin their careers as educators will influence the development of their own students’ brains.

Life’s Replica Project description

To create a meaningful science learning project based on problematization, a professor from a college of education collaborated with an elementary science teacher from a laboratory elementary school. The project was titled Life’s Replica: Youth Aware of Their Environmental Impact and Role in Society (Life’s Replica Project). The project, implemented between August 2019 and December 2019, was the main component in two core courses of a teacher preparation program: (i) EDPE 4122, Seminar: Curriculum, Instruction, Learning, and Evaluation II; and (ii) EDPE 3237, Teaching Science at the Elementary Level. In total, there were 29 preservice elementary teachers (PsETs) and 32 sixth-grade students (6gSs) participating as part of their science class. The pedagogical purpose was that the project would provide PsETs with a real-life experience of how elementary students learn science in a meaningful way.

The strategy to develop the learning activities consists of the combination of a problem, a project, and service learning, as recommended by Velázquez Rivera and Figarella García (2018). The Life’s Replica Project served as the context for this problem-project-service strategy in which participants investigated a problem, developed a product, and provided community service. The implementation of the project involved three phases: Challenge, Collaborative, and Creative. Each phase included core activities that facilitate problematization in learning (see Figure 1). Some characteristics of the core activities of the project were (i) continuous inquiry, (ii) school integration with the external community, (iii) individual and collective learning and assessment, and (iv) integration of technology as a tool to learn and demonstrate learning.

Challenge phase

Core Activity 1: Motivational situation

In the strategy established by Velázquez Rivera and Figarella García (2018), the first core activity consisted of presenting the problem to the students through a motivational presentation of news headlines and images about the human impact on Earth’s ecosystems. This activity aimed to promote critical thinking and facilitate the development of
cognitive conflicts. The presentation led students to think about how human beings can put the conditions of life on Earth at risk, then they were invited to brainstorm about what people could do if life on Earth was no longer sustainable due to the impact caused to the planet and its limited resources. The discussions of the digital presentation motivated students to seek out solutions, awakening in them a greater sense of responsibility.

As part of the motivational situation, a member of the United Nations Association of the United States of America in Puerto Rico (UNA-USA PR) requested that the PsETs and the 6gSs collaborate to promote the achievement of the United Nations Sustainable Development Goals (SDGs). The PsETs were assigned to act as educators who created and developed educational materials (i.e., curriculum units) that contribute to the teaching and learning about the SDGs. The 6gSs were tasked with playing the role of eco-engineering ambassadors of sustainability to develop solutions to problems caused by human impacts on Earth. Although both groups of students agreed to play the roles requested and participate in the project, it was evident they had more questions than answers.

**Core Activity 2: Clarification with KWH table**

The clarification with the KHW table (know, want to know, and how will we learn it) was the second core activity in problematization, intended to further awaken the need to learn (Velázquez Rivera & Figarella García, 2018). To engage students and make it easier for their voices to be heard, teachers asked students to complete the KWH table (see Figure 2).

The preservice teachers’ answers in the first column allowed them to identify their knowledge of creating lesson plans and activities that facilitate science learning. In the second column, they generated questions such as the following:

- What distinguishes science from other subjects?
- What should a citizen know about science?
- What is science literacy?
- What educational practices facilitate science learning?
- What characteristics should the educational materials have to facilitate meaningful science learning?

In the third column, they included activities to learn and investigate, such as talks by experts, literature reviews, and the formation of work groups to develop the educational materials. In this column, they also included field trips to ecosystems to learn about their characteristics, the interactions necessary for life, and how these ecosystems are being affected. The identification of learning activities by the PsETs contributed to their autonomy and self-direction, therefore facilitating meaningful learning.

**Collaborative phase**

In the Collaborative phase, there were different types of collaboration between PsETs and 6gSs, promoted through formal learning activities, as established by Velázquez Rivera and Figarella García (2018) in their problem-project-service strategy.

**Core Activity 3: Online discussion forum**

An online discussion forum was developed to provide the PsETs with the opportunity to engage with elementary students and discover the methods in which they effectively learn science, as well for 6gSs to begin learning about science ecology content. The topics assigned to the 6gSs included forests, coral reefs, estuaries, and hydrography. They needed to answer several questions about the topic to create a digital presentation. The PsETs did some research on the topic to provide recommendations that would help the 6gSs improve the content presented, which also helped the PsETs learn about the nature of science, how to facilitate meaningful learning, and how to develop scientific literacy.

**Core Activity 4: Conference**

One of the activities considered required in the KWH table was learning from experts. For both the PsETs and the 6gSs, it was necessary to know what the UNA-USA PR and the SDGs are. With this goal in mind, both groups were invited to participate in a conference offered by the executive director of UNA-USA PR, who, in addition to talking about the association he represents, motivated them to contribute to the achievement of the SDGs. At the end of the conference, the PsETs realized the need to get involved in Education for Sustainable Development and expressed their commitment to the project.

**Core Activity 5: STEM workshop**

As part of the project, the PsETs had to support the 6gSs in the creation of a biosphere in which the conditions necessary for life were replicated.

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**FIGURE 2**

*Clarification with KHW table.*

<table>
<thead>
<tr>
<th>What do we know?</th>
<th>What do we want to know?</th>
<th>How will we learn it?</th>
</tr>
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<tbody>
<tr>
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Creating this biosphere required the integration of science, technology, engineering, and mathematics (STEM) design. To learn about STEM education, the PsETs participated in a 1-day workshop offered by experts from Starbase PR, a program developed between the United States Department of Defense and the National Aeronautics and Space Administration (NASA). In addition to learning about STEM, PsETs who took this workshop found it easier to recognize the importance of STEM in school curricula and the need to educate about engineering design in any school subject.

**Core Activity 6: Field trips**

Two field trips allowed the PsETs to experience how the 6gSs learn science in a meaningful way because the PsETs interacted as in-service teachers.

The first field trip was a 1-day excursion to El Yunque National Forest and the estuary of the Espíritu Santo River in the northeastern part of Puerto Rico. The students were taken on an explorational hike through the forest and a boat tour through the river estuary, which allowed them to directly observe the interactions that occur in this ecosystem and how they are being affected (see Figure 3). The PsETs then assisted the 6gSs in completing their log books at the same time that they were learning about ecosystems.

The 2-day residential trip to ecosystems in the southwestern part of Puerto Rico was significant for the PsETs. First, they visited Las Salinas, an area of great historical and ecological value where students could enjoy lagoons, salt marshes, dry forest, and mangroves. Second, they attended a legislative session of the Cabo Rojo Municipal Assembly in which various environmental conservation projects were presented, which enabled the PsETs to learn about democratic processes that facilitate governmental decision-making. At the end of the session, the participants in the Life’s Replica Project were declared distinguished guests of the municipality. Third, the PsETs planned and implemented different learning centers with STEM content activities for the 6gSs. These activities required the application of engineering designs to replicate life-sustaining conditions in space. The topics of the learning centers were as follows:

1. Impact to the atmosphere: how to collect space garbage (Figure 4)
2. Life in space: how to pack food (Figure 5)
3. Life in space: how to protect ourselves from solar radiation? (Figure 6)

In general, the PsETs engaged the 6gSs in applying ecological concepts they were studying, as well as in using scientific skills (e.g., observing, infer-
Preservice Teachers’ Meaningful Science Learning

ring, predicting). They exchanged ideas through both oral and written communication and experienced together how to learn in a scientific way.

Creative phase

As part of the Creative phase, the PsETs had to apply what they had learned and present it to the general community and to experts who collaborated on the project.

Core Activity 7: Creation of educational materials and their presentation

The PsETs created the educational materials (curriculum units) by applying what they had learned as part of the project and their college courses. The product was four elementary-level curricular units (promoting SDGs and Education for Sustainable Development). Each unit focused on the problematization of learning of some of the SDGs and used a problem-project-service strategy as a context to awaken students’ need to learn about the SDGs. The units promoted curricular integration by incorporating meaningful science learning into nine subjects: science, mathematics, language arts, social studies, physical education, health, fine arts, music, and theater. During the closing activity, held at the beginning of December, the PsETs presented their curriculum units and donated a copy to the UNA-USA PR. These units were adopted as part of the organization’s educational materials, and the accomplishments of the project’s participants were recognized and celebrated.

Preservice elementary teachers’ meaningful science learning

The project’s assessment outcomes collected the PsETs’ unique voices through the answers gathered in the KWH table, group reflections on their experience in the core activities of the project, and the creation of the educational materials (curriculum units). Overall, the PsETs learned the importance of being well informed in order to help others improve their work; the need to integrate the SDGs in their classrooms as part of the curriculum; the utility of STEM as an interdisciplinary approach that seeks to enhance students’ capacities; the value of field trips to experience and learn new things firsthand; and the significant experiences they can provide through residential trips. The online appendix shows supporting examples of PsETs’ groups learning reflections on problematization in the core activities of the project.

In relation to the creation of the educational materials, one PsET group’s reflection affirmed that they were able to use high levels of thinking by applying what they learned in the project as follows:

The experience of creating a unit promoted the use of high levels of thinking because we had to understand, interpret, and analyze new information related to the science curriculum. At the same time, we had to develop activities and instruments to evaluate learning, which required making decisions about the objectives we set. We had to develop or modify activities that promoted reflection, creation, and other levels of thinking necessary for meaningful learning. The activities sought to problematize the situation, to facilitate students’ discovering the relevance of the subject studied, and to create a cognitive conflict that leads students to search for a solution on their own. Everyday life is about conflict, and we must provide experiences that help the students question and look for possible solutions. Society moves fast, so learning cannot be limited to memory levels.

Table 1 shows how the high levels of thinking (e.g., analyze, reflect, investigate, create, act, evaluate), as established by Velázquez Rivera and Figarella García (2018), were developed through some of the project’s core activities.

Conclusion

The Life’s Replica Project provided a context for PsETs to learn about the nature of science by analyzing human beings’ impact on Earth’s ecosystems. PsETs also developed scientific literacy as they designed a plan for a learning center and created a curriculum unit that promoted meaningful science learning at the elementary level. The project’s strategy strengthened PsETs’ learning as they investigated a problem, developed a product, and provided community service. The collaboration between PsETs and 6Gss in the project also contributed to participants finding meaning in learning science by applying science in real-life situations. In conclusion, this collaborative project served as an example of a relevant teaching and learning experience that can promote preservice teachers’ meaningful science learning and improve college science education by preparing scientifically literate teachers.

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References


Preservice Teachers’ Meaningful Science Learning

| TABLE 1 |
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| **Core activity** | **High-level thinking** |
| Online discussion forum | PsETs **evaluated** the work of the 6gSs and offered recommendations for improvement. |
| Field trips | PsETs **evaluated** the effectiveness of their role while leading the learning process of the 6gSs group assigned to them to improve their performance. |
| Creation of educational materials (curriculum units) | PsETs **investigated** and deepened their knowledge about the Sustainable Development Goals. PsETs **analyzed** the information, resources, and materials to decide how to integrate them into the curriculum unit. PsETs **created** a curriculum unit for elementary students that promoted the integration of nine subjects and facilitated problematization (including all the corresponding materials and resources to be donated). PsETs **reflected on** and evaluated their experience of creating and donating the curriculum unit, identifying new ways to promote education in sustainable development. |


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