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Scientific Communities of Practice: A K12 Outreach Model That Supports Authentic Scientific Inquiry Around Very Long-Term Studies

Steven McGee[1]*, Jess K Zimmerman[2], Randi McGee Tekula[3], Normandie González-Orellana[4] and Noelia Báez Rodríguez[5]

[1]*The Learning Partnership, USA*

[2]*University of Puerto Rico, USA*

[3]*The Learning Partnership, USA*

[4]*Forward Learning, USA*

[5]*University of Puerto Rico, USA*

Corresponding author: Steven McGee, The Learning Partnership, USA

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Abstract

Scientific outreach to K12 education typically centers around the direct dissemination of scientific findings or by engaging students in citizen science data collection. Rather than viewing science outreach purely through the lens of knowledge transmission or through the lens of specific data collection practices, we present a view of science outreach as a bridge to bring K12 students into ecologists' communities of practice. We exemplify this outreach model using the Luquillo Long-Term Ecological Research (LTER) Schoolyard program as an example. The schoolyard program brings middle-school and high-school students into the Luquillo LTER community of practice through authentic scientific inquiry with long-term ecological data. Long-term data provides an essential means for students to investigate large-scale, long-term phenomena and develop essential data science skills.

Key Words: Communities Of Practice; Education Outreach; Long-Term Ecological Research; Long-Term Data; Luquillo Experimental Forest

Introduction

Engaging students in the process of scientific inquiry is essential for the development of scientific knowledge, expertise in scientific practices, and a scientific identity. For many areas of science, short-term, concrete phenomena can readily be investigated in the classroom. For example, students can derive many principles of physics through hands-on experimentation in the classroom. In addition, observations of the local environment around the school can lead to insights about the behavior of animals and plants. However, it is impractical for students to gain direct experience with large-scale, long-term phenomena, such as climate change or ecosystem succession. All too often, students learn about large-scale, long-term phenomena by reading scientific explanations, examining premade conceptual diagrams and graphs, or engaging with simulations. Very rarely do students directly engage in investigations with large scale, long-term data, even though there is a tremendous explosion of publicly available, long-term environmental datasets (Soranno et. al., [1]). As a result, this lack of exposure to long-term data limits the opportunities for students to develop expertise in working with long-term data (NASEM, [2]).

The opportunity to authentically engage with long-term data is hampered by the structure of modern schooling. The standards-based movement, which began in the 1990's, reached a pinnacle with No Child Left Behind and Race to the Top (Au [3]). Both pieces of legislation enshrined in law an accountability regime focused on assessing college readiness in math, English Language Arts, and science. Despite an emphasis on inquiry in the Common Core Math and Next Generation Science Standards, high-stakes assessments have constrained what is taught and how it is taught (Au [4]). The predominant content of math and science are the bite-sized pieces of knowledge that appear on the assessments. To maximize the coverage of the content that appears on high-stakes assessments, the predominant mode of instruction is teacher-centered (Au [4]). The emphasis on college readiness signals to students that the content is not necessarily relevant to their current lives but is important because it will prepare them for the future (McGee et al., [5]). These conditions thwart opportunities for students to develop connections to the phenomena they are studying, to explore phenomena of interest to them now, and to authentically use long-term scientific data to explore phenomena of interest.

Within this framework of standards-based education, scientific outreach to K12 education typically centers around the direct dissemination of scientific findings in bite-sized pieces or by engaging students in citizen science in which participants use pre-existing, standardized protocols for collecting and submitting data, with limited opportunities to use that data for authentic investigations (Penual and Means, [6]). These disconnected experiences often lead to a distorted view of the scientific enterprise. Rather than viewing science outreach purely through the lens of knowledge transmission or through the lens of specific data collection practices, we present a view of science outreach as a bridge to bring K-12 students into the communities of practice of ecologists (Lave and Wenger, [7]). We exemplify this outreach model using the Luquillo Long-Term Ecological Research (LTER) Schoolyard program as an example. The schoolyard program brings secondary students into the Luquillo LTER community of practice through authentic scientific inquiry with long-term ecological data about the El Yunque National Forest in Puerto Rico.

Legitimate Peripheral Participation

Our goal with the Luquillo LTER Schoolyard program is to engage students in Luquillo science as junior members of the community. The Legitimate Peripheral Participation framework (Lave and Wenger [7]) provides the framing for how we engage students as junior community members. Lave and Wenger highlight the inherent conflict that exists in school settings that are structured around teaching practices. The content of school instruction emerges from specific communities of practice; however, students are rarely positioned as legitimate peripheral participants with reference to those communities where the content of instruction emerged. Instead, students are often positioned as legitimate peripheral participants with reference to the community of educated adults. The Legitimate Peripheral Participation framework provides a lens by which to examine and structure how we can provide students with opportunities in the classroom to be positioned as legitimate peripheral participants with respect to the scientific community. There are five key characteristics of the framework that can be embedded in school contexts to engage students as legitimate peripheral participants. The first two characteristics described below focus on the relationship of the student to the community. The last three characteristics described below focus on the legitimacy of student participation in the community.

Identity Development

Lave and Wenger characterize learning as movement from the periphery of a community to becoming a central member of the community. "…a deeper sense of the value of participation to the community and the learner lies in becoming part of the community… Moving toward full participation in practice involves not just a greater commitment of time, intensified effort, more and broader responsibilities within the community, and more difficult and risky tasks, but, more significantly, an increasing sense of identity as a master practitioner." (pp. 111-112) Within an education context, John Dewey asserts that "as soon as [students are] possessed by the emotional attitude of the group, [their] beliefs and ideas will take a form similar to those of others in the group. [They] will also achieve pretty much the same stock of knowledge, since that knowledge is an ingredient of [their] habitual pursuits." (Dewey, [8]) It is imperative to support the development of student identity as a member of the community.

Learning Sequence

At the outset of learning, students are not able to successfully engage in all aspects of scientific practice. "A newcomer's tasks are short and simple, the costs of errors are small, [and] … tend to be positioned at the ends of branches of work processes, rather than in the middle of linked work segments." (p110) "Production activity-segments must be learned in different sequences than those in which a production process commonly unfolds…" (p.96) Within the context of an apprenticeship approach, students will experience the entire process of an investigation, but focus on completing specific steps independently. For example, given a specific research question, a set of data related to the research question, and graphs displaying patterns in the data, students may focus on interpreting the graphs to provide evidence for an answer to the research question. As they develop facilities with interpreting graphs, they may begin to take on generating graphs in subsequent investigations.

Scientific Practices

To be considered legitimate peripheral participants, some people may think that it is necessary for students to be contributing to the scientific community through activities such as citizen science. However, Lave and Wenger (1991) argue that being positioned as a legitimate peripheral participant depends largely on the extent to which students are engaged in the scientific practices of the community. "...opportunities for learning are, more often than not, given structure by work practices instead of by strongly asymmetrical master-apprentice relations." (p.93) The Next Generation Science Standards place a significant emphasis on engaging students in the practices of science to learn disciplinary core ideas. Despite the proclivity of schools to narrow the content of what is taught and how it is taught (Au [4]), engaging students in the process of inquiry is correlated with higher outcomes on standards-based assessments (Allensworth et al., [9]; McGee et al., [10]; McGee et al., [5]).

Scientific Tools

As legitimate peripheral participants, students learn to use the scientific tools of the community. Lave and Wenger [7] use the term transparency to characterize this learning process. "...the term transparency when used here in connection with technology refers to the way in which using artifacts and understanding their significance interact to become one learning process." (pp. 102-103) Lave and Wenger use the metaphor of a window to exemplify how transparency involves both invisibility and visibility. The window is invisible in that it provides visibility to what is outside of the room. The salient phenomenon is the subject matter that the window reveals. The wall on the other hand is visible and salient and does not reveal the subject matter of interest, namely what is outside the room. Scientific tools move from a position of visibility and salience to a position of invisibility, thus making salient the phenomena of interest to the community.

Learning the Language

Becoming a member of a community is more than just an increasing ability to engage in the tasks. It is also dependent on building social bonds with other members of the community. "For newcomers then the purpose is not to learn from talk as a substitute for legitimate peripheral participation; it is to learn to talk as a key to legitimate peripheral participation." (pp. 109-110) Communication is key to developing bonds around the goals of the community as well as sharing what is learned from practice. It is essential for newcomers to be able to use the language of the community.

Luquillo LTER Schoolyard Program

The Luquillo LTER Schoolyard program has three primary strands of activities: Journey to El Yunque, Data Jam, and Field Work protocols. Across the three strands of Schoolyard activities, students use long-term data to investigate key questions related to the Luquillo LTER, namely hurricane and drought disturbance. Students work with long-term data related to hydrology, biogeochemistry, and population dynamics of specific consumers (e.g., shrimp, coquí, anole, snails). Having access to long-term data is crucial to engage students in authentic inquiry around long-term, large-scale phenomena, such as the intermediate disturbance hypothesis.

With Journey to El Yunque, middle school students use long-term data to study past hurricane disturbance and resilience (McGee & Zimmerman, [11]; McGee et al., [12]). With Data Jam, middle and high school students develop their own investigations around long-term biotic and abiotic data collected by the Luquillo LTER (Delgado-Quiñones, McGee et al., [13]; Delgado-Quiñones, McGee & Baez-Rodriguez, [10]). With the Field Work protocols, secondary school students contribute to the development and investigation of long-term datasets about a specific plot near the Luquillo research station.

The legitimate peripheral participation framework provides a means for sequencing the Luquillo LTER program of scientific outreach. The sequence of Journey to El Yunque, Data Jam, to Field Work Protocols introduces students to the scientific practices in the opposite order in which scientific inquiry unfolds. With Journey to El Yunque students are provided with an investigation question, Luquillo long-term data and models about population dynamics and they are expected to develop a scientific explanation of how hurricanes directly and indirectly impact population dynamics. With Data Jam, students are provided with Luquillo long-term data and are given the opportunity to ask their own research question and analyze the data to develop a scientific explanation. With the Field Work Protocols students collect data and contribute to a long-term dataset of forest productivity in a plot near the Luquillo El Verde Field Station. Students can then ask their own research questions about tree biomass analyzing the long-term tree productivity data to develop a scientific explanation. Across the three Schoolyard strands, students use modeling and data analysis software as scientific tools. The tools are designed for students so that the tools can serve as a window to the phenomena. Through the process of engaging in scientific argumentation from evidence and receiving feedback from their teachers, students develop facilities with the language of science. Our prior research has shown that the context of serving as junior members of the Luquillo community does support student identity development as ecologists (McGee et al., [12]).

The legitimate peripheral participation framework guides the design of the Luquillo scientific outreach program to align the experiences of the students with the scientific community. As the program activities were being developed, careful attention was also paid to the connections to the educational standards so that the activities have a place within the school curriculum. Providing opportunities for students to use long-term data is essential for them to investigate large-scale, long-term phenomena. The legitimate peripheral participation framework provides a means for scientists to design experiences in such a way as to bridge classroom practices and scientific practices [13-16].

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