Teachers Partner with Scientists to Learn the Relevance of Mathematics Through Climate Research

Susan Nickerson, Talia LaTona-Tequida, and Samuel S.P. Shen

How can we support K–12 teachers to convey the relevance of mathematics to their students? How can we support teachers in understanding the purpose of practices of the mathematics discipline? How can these practices contribute to a growing body of disciplinary knowledge? An NSF-sponsored project at San Diego State University (SDSU) is attempting to address these questions. In the summer of 2021, seven K–12 mathematics teachers participated in a climate science research lab. The seven, together with some science teachers, participated in a five-year NSF-funded professional development project to support their development as teacher leaders. One teacher describes the impact of the NSF experience:

> *The summer experience with the data science/math lab and [the director] has encouraged me to meet with my math and science teaching teammates in my middle school to talk about how data science (specifically related to climate change) can be brought into our classrooms to make our content both connected and relevant.... We are using the 4DVD [4-Dimensional Visual Delivery] model to have data talks in both math and science classes and it is fun to hear kids talking about the model. Two of the history teachers are also using the model to see climate data during certain times in history.*

Research experiences for teachers (RETs) have been widely used as professional development opportunities for K–12 science teachers. The goal of RET programs is to support the active involvement of K–12 teachers in STEM research in order to bring a more complete understanding of these disciplines to their students as a result of their participation (NSF, 2021). We adopt the perspective of Lave and Wenger's (1991) communities of practice (COP), which describes learning as situated. More specifically, novice members of a community learn as they engage in legitimate peripheral participation through apprenticeship, moving toward more central roles as they adopt practices specific to that community. Providing opportunities for

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mathematics teachers to engage in a research lab allows the teachers to experience, firsthand, a community of mathematical practice (CoMP). The teachers can translate these practices to the students in their classrooms. Teachers are often the first mathematics promoters; they teach students how to use mathematics to solve problems and also encourage some students to become professional mathematicians.

The climate lab was a fitting context for a RET, given that the California state K–12 science standards require teaching about climate science. Mathematical modeling, one of the conceptual categories of the Common Core high school standards for mathematics (National Governors Association, 2010), is prevalent in climate science.

In the following, we describe the goals of the project, details of the activities, and what teachers report they gained from the experience. We end with suggestions for research mathematicians who wish to provide similar opportunities for mathematics teachers.

Goals and Activities

The goal of this RET was to support teachers as they: 1) engage in a community of mathematical practice (CoMP), 2) develop understanding of how mathematical knowledge builds, and 3) gain understanding of the relevance of mathematics that they are teaching and what one can do with a mathematics degree.

Given the evolving conditions of the COVID pandemic, we met virtually for a month. Four days a week, there was structured time with the lab director; roughly an hour each day was formal "instructional time." Teachers spent the remaining hours on these days attending two lab meetings each week, working with each other and with two mathematics education researchers at SDSU on learning tools, replicating research, and generating questions. There was unstructured time for teachers to work independently or to get their questions answered by the director. One day a week was dedicated to a pair of activities: virtual visits from research mathematicians and scientists, and working with two secondary teacher leaders (peer coaches) to reflect on the implications of the experience for their work as classroom teachers.

The lab experience began with the lab director giving an overview of what we know and are learning about climate change. His routine was to pose a question, beginning with "What are the top four most abundant gases in the atmosphere, and why are such small amounts of greenhouse gases a major concern?" and "How do we accurately obtain the historical time series data of global warming, given that the climate data have been collected from weather stations around the world?" Teachers generated questions based on what they learned and investigated. For example, "How do you mathematically account for the fact that data collection points aren't evenly distributed?"

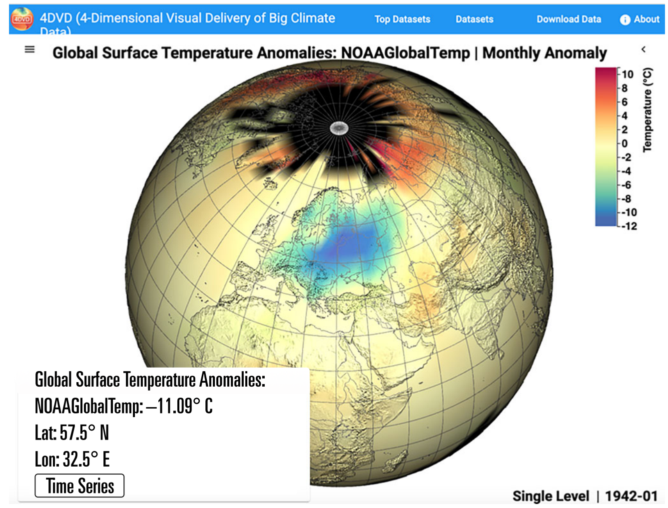

Figure 1. The blue region on the globe is a 4DVD display of the cold Europe temperature anomaly in January 1942. The unusual and about −11°C colder than normal winter in the Moscow region helped the Allies defeat Hitler's attack on the Soviet Union.

They also began early in the lab experience to learn the use of tools, primarily R programming. The other tool was database software developed at the Climate Informatics Laboratory, *4DVD: 4-Dimensional Visual Delivery* of big climate data (`https://4dvd.sdsu.edu`). See Figure 1. None of the teachers had prior experience with 4DVD data or R programming.

The director presented them with two possible research projects. They could explore: "What was the lunar surface temperature at the location and time of Armstrong's landing on the Moon in 1969?" or "Calculate the height of a mountain of your choice." These were historically significant and real research questions for professional scientists and engineers, but now can be answered by simple climate models and R code. Teachers learned about a class of climate models known as energy balance models (EBM) that are simplified representations of key aspects of the climate system (atmospheric and oceanic flows are not considered). In particular, they used an EBM to model the moon's surface temperature. They also examined air pressure, temperature, and elevation, and applied the hypsometric equation, a functional relationship among elevation, pressure, and temperature, to calculate the elevation of Mount Mitchell, the highest point in the United States east of the Mississippi River.

In the lab meetings, the teachers also got insight into the current research questions being investigated by the lab. Initially, the students who work in the lab with the director were asked to conduct the lab meeting as they would ordinarily; the teachers were observers. To gain a broader perspective of the lab's work, the teachers also read three papers published by the lab researchers. After the teachers had attended a meeting or two of the smaller focused lab groups, teachers shifted to asking questions and interacting with the other lab members. In subsequent days, as they worked on learning tools and conducting research, the director would ask them to share their screen with data or results, particularly if there was a challenge they were trying to resolve. In this way, the relationship between the CoMP of the lab and the teachers shifted from teachers as novice observers of the lab interactions to legitimate peripheral participants (Lave & Wenger, 1991) as they replicated research and regarded the lab director as a mentor.

What Teachers Reported Learning

To gain understanding of what teachers learned from participation in the RET, we asked them to keep a journal of what they worked on and the questions they had, and to complete two surveys. We also took notes and recorded most of the meetings with the director and peer coaches.

We believed as they engaged with a community of mathematical practice (CoMP), they would be better positioned to engage students with the K–12 Common Core State Standards for Mathematical Practice. The Standards for Mathematical Practice outline practices that mathematics learners at all levels should develop (National Governors Association, 2010) (https://www.nctm.org/ccssm). These standards "...describe the contours of mathematical practice; the various ways in which proficient practitioners of mathematics carry out their work." (McCallum, 2012).

Teachers entered with their own professional knowledge about mathematical practices and explicitly or implicitly cited multiple practice standards, including the four listed here:

1) Make sense of problems and persevere in solving them. (Practice 1)
2) Construct viable arguments and critique the reasoning of others. (Practice 3)
3) Model with mathematics. (Practice 4)
4) Attend to precision. (Practice 6)

These practices were often connected. For example, a few teachers described their efforts at using the hypsometric model to determine the height of a mountain whose height was public knowledge. They constructed their models and computed how accurate their model was. They then made a judgment about the precision of the results and then revisited the model, making adjustments to the data they used until they reached a precision standard outlined by the director. See Figure 2.

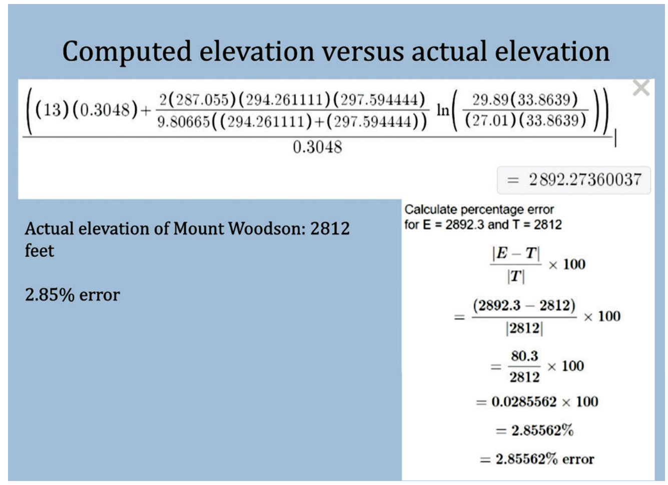

Figure 2. Computing elevation and its error using hypsometric equation for a local mountain: Mount Woodson weather station (33.0087°N, 116.9709°W).

We also wanted them to develop a richer understanding of the nature of mathematics and how mathematical knowledge builds. They observed experienced researchers in a lab. They noted the way in which the director recognized and drew on different people's expertise even while the focus of the group was on the collective solving of a problem. One teacher wrote:

> [*Director*] *worked with all of us in the same way and gained our trust and respect while causing us to learn coding to represent data. ...when reflecting on the experience, the conversations were always about the work being done, what the students (or we) knew how to do and then building on what we knew to push* [*our work*] *forward. Especially with the programming in R. We shared the code we built, looked at the code and discussed what was in front of us. We noticed what worked and learned from what didn't.*

They cited the fruitfulness of solving a simpler problem:

> *I found it interesting that we use an easier model, like the moon, to understand predicting climate and temperature before we move on to the much more complicated task of predicting climate/temperature for the earth where we have atmosphere, wind, rain, etc. to make things much more complex.*

They also recognized the role of failure in research and learning in general:

> *Ask questions, ask them often, start early. Failure is how you learn. Bad results are still useful. You learn from them and redesign. Most of the research is not successful.*

Finally, we hoped they would gain a better understanding of the relevance of mathematics and data. A trigonometry teacher reported a better understanding of why she would teach indirect measurement:

> *This week I really dove into the hypsometric equation and approximating elevation using temperature and air pressure. I thought it was pretty interesting to use this model by having what you could measure. For example, you can measure temperature and air pressure but it is really hard to measure elevation or height. So, you could use this model to solve for the height when you knew the other two things and gravity and gasses were pretty constant.*

Teachers cited learning or relearning why the focus on domain and range was important, the conceptual underpinnings of the line of best fit, and almost all of them cited their new or renewed understanding of the importance of coding and computational thinking.

All these things had some connection to their teaching. As they learned about the processes and proficiencies of research mathematicians, they wanted to support their students in developing these proficiencies. Given their experience as learners, several noted the importance of perseverance and reported that they had greater empathy for the challenges faced by students and wanted to make room for students to have more time to "ruminate" on bigger problems. They made a connection between the mathematical modeling process and the modeling process in which they engage as teachers.

> *In the same way the summer lab work there was this constant thing about results/feedback just being information. When trying things out and something didn't work out it... gave you information on what to fine tune. Specifically in the climate group there was a lot of work around debugging and one of the presenters talked about how they had encountered an issue with their designing software. The way people apply their skills in the real world and get results, we need to examine student work similarly... we get feedback about what a student may understand or need help bridging.*

Summary. Research experiences for teachers are constructed as a way to enable teachers to translate the practices of the community of research scientists and mathematicians to their students. In addition to the relevance of mathematics, our teachers reported having learned about perseverance in problem-solving, the nature of communication in a technical field, mathematical modeling, and the importance of precision. This supports them as "promoters" of mathematics. Through their participation in a mathematics research lab, they reported an increased understanding of the way mathematical knowledge increases. They reflected on how it would impact their instruction, both in their classroom and the classrooms of their peers who they reported recruiting to bring data science into the classroom to make it "connected and relevant."

What We Learned

We found the experience fruitful and rewarding. If you are considering engaging mathematics teachers in your lab, note:

1. RET experience is short-term and must be constructed with a focus on tools or techniques teachers can learn and a research task they can complete in an abbreviated timeframe.
2. Think deliberately about how teachers will integrate into the work of the lab. Remote work can inhibit the feeling of being integrated into the lab, but attendance at lab meetings and deliberate invitation to share their work with others can foster a sense of belonging.
3. Consider the relevance of your lab's focus to K–12 standards. The mathematics they are doing in the lab should have a link to the mathematics they are teaching *or* support the teaching of mathematical practices.
4. Teachers need time and space with other teachers to reflect on the connections to their classroom teaching. If you do not have the expertise to lead them in this reflection, have a local teacher leader facilitate sessions in which teachers reflect on connections between what they are learning and their practice as teachers.
5. Visiting research scientists and mathematicians described uses of mathematics and, in the process of discussing their work, communicated messages about research that were aligned with what the teachers were experiencing. For example, failure is a part of learning.
6. These teachers were part of an NSF-sponsored program that gave them compensation for a month of working in a lab. You will need to seek out a partner working with teachers or seek additional funding, perhaps through a grant supplement.

We were excited to open the lines of communication between research mathematicians and teachers. The latter may gain a richer understanding of mathematics and an understanding of a research area as significant as climate change. We encourage you to do the same. RETs may be an important part of in-service teacher education. The benefits for teachers yield benefits for students – our future mathematicians and scientists.

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Credits

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