A magazine for mathematics
and science educators

TERC

FALL 2024

1 Climate and Equity Institute:
A model for transformative professional learning

CONTENTS

Letter from the President

The Fall 2024 issue of TERC's *Hands On!* magazine represents a compilation of TERC's research where we are exploring, capturing, and sharing learning in various places via a variety of voices. At an art museum, in the classroom, through a competition, or at a remote Maine seacoast, learning happens, and our work provides the activities and supports to aid in a lasting and growing outcome beyond the projects themselves.

In *Climate and Equity Institute*, experienced teachers from across the U.S. are brought together at the Maine seashore for a week. They explore the importance of connecting/re-connecting with nature and empowering students to take action to help combat anxiety and feelings of despair and powerlessness.

Using Math to Connect Intergenerational Museum Visitors with Art brought together grandparents and their grandchildren, art museum education curators, and a TERC researcher to explore the connections between math and art at the Georgia Museum of Art at the University of Georgia. One of the main goals for bringing math into the art museum was to help visitors make connections between the art and what they know from outside the museum.

Innovate to Mitigate: The Impact of Social Media on Green Roofs is a reflection of two team leaders in the Innovate to Mitigate annual national competition to help guide and design solutions to limit the impacts of climate change.

Virtual Coaching to Visualize Teaching: Reflections of a Virtual Math Coach explores the use of math instructional coaching to help teachers incorporate math argumentation into their teaching. A passionate teacher with some classroom experience currently pursuing her Ph.D. shares her impressions of a virtual coaching experience, engaging as a learner alongside teachers.

Laurie

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Climate and Equity Institute

A model for transformative professional learning

GILLIAN PUTTICK &
BRIAN DRAYTON

Eleven high school teachers selected from more than 90 applicants came to the Schoodic (Maine) Institute from July 21st to 27th, 2024, for TERC's third Climate and Equity Institute, funded by the John D. and Catherine T. MacArthur Foundation. Teachers came from both coasts, northern and southern states, and the middle of the country. As in previous years, teachers came in roughly equal numbers from rural, urban, and suburban schools serving a wide diversity of students. The pattern of the week was similar to that developed in the first two years. Every day was packed!

Dr Eric Nadeau leads a discussion about the impacts of climate change on shore biota

About the project

The Climate and Equity project (terc.edu/climateandequity) plans to transform how climate and equity are taught by reducing teacher isolation and supporting collective growth.

Goals: The incidence of extreme climate impacts is increasing. Levels of eco-anxiety and existential dread related to global warming among youth are at record highs. Education about global warming, and its inequitable impacts, is urgently needed, yet teachers who address this need are isolated. The project hosts small groups high-school teachers at a one-week, expenses-paid Climate and Equity Institute at the Maine seashore. Teachers discuss and exchange ideas and best practices for equitable pedagogy, discuss the global and psychological impacts of climate change, explore climate change impacts firsthand through guided field trips, and have ample free time to enjoy the Maine woods and seashore.

Outcomes: Teachers will become founders of a national network of colleagues and leave with a renewed sense of hope and purpose.

To help teachers make the most effective use of our time together, we have worked to make our design principles as explicit as possible for the teachers, so that they can use our thinking to support their own sense-making. To this end, our team has done a top-to-bottom examination of our design. We found that all the various strands of this complex week can be summarized under three categories — Pedagogy, Biocomplexity, and Equity (**Figure 1**).

Our design for these institutes has many layers, aimed at supporting the teachers' learning and reflection. What we cannot schematize is how the people who gathered at the Institute made these ideas into living action. The teachers and invited session conveners (speakers) all brought their history and expertise, and also their open questions about their own practice, and the experiences of their students. The Institute succeeded, we believe, in creating a setting in which this rich wealth of experience as well as dilemmas of practice, could be addressed together. One teacher's response in a post-survey about the institute overall exemplifies what we have heard from teachers over the last three iterations,

> *From the beginning, the institute was a breath of fresh air, literally and figuratively. The efforts that were made to create a particular professional development experience centered around the driving question—what are the qualities that distinguish effective climate education and equity—were palpable... The variety of activities, including opportunities for deeper reflection and sharing... set the conditions for our particular cohort to gel in a way that some of us may have hoped for but none of us really expected. This underscored the importance of creating "brave spaces" for me as I really think that the quality of the experience was determined by how much people felt welcomed and encouraged to bring their whole brilliant selves to the table. (Evelyn)*

> *I feel like it shifted my thinking in some big picture ways. It's not so much about specific activities or lessons (although there are a few of those). It's more about bigger concepts like the power of narrative for developing empathy, making climate instruction more trauma-informed, maintaining active hope, and humanizing education in general. (Megan)*

The three Institute components

We define biocomplexity as human-nonhuman interdependence, and the inclusion of politics, laws, history, economics in science. Because biocomplexity infused all discussions during the week, we describe the other two Institute components, Equity and Pedagogy, in more detail below.

Equity

The institute began by emphasizing teacher voice and leadership: each teacher introduced themself and their

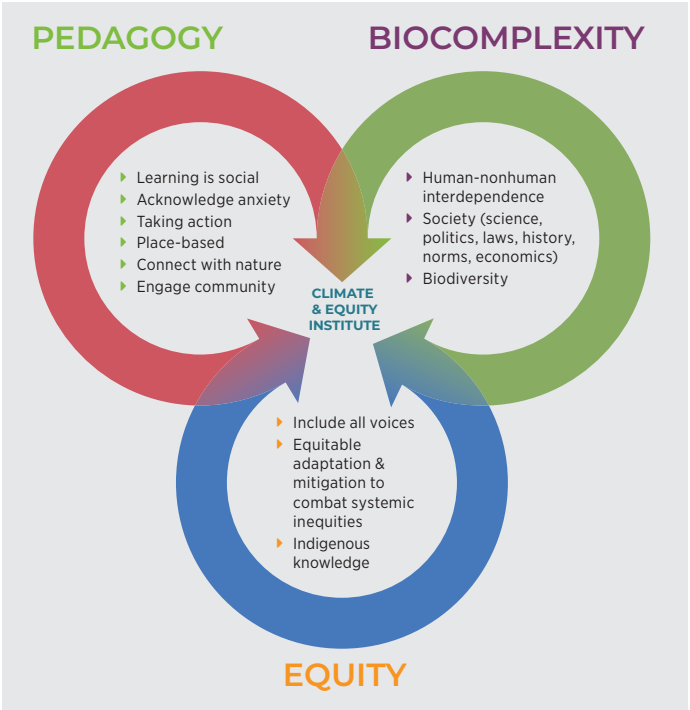


Figure 1 | Biocomplexity, Pedagogy and Equity, three components of the Institute framework.

The Climate and Equity Project group.

practice on the first day. Each teacher raised some issue of equity, either as a success or a challenge in practice, related to, for example, addressing inequitable classroom practices or talking about the inequitable impacts of climate change due to systemic inequities. Diana De Paula, a 2023 Fellow, picked up on these threads and led an inspiring presentation and discussion on the meaning and practice of equity in the science classroom, a conversation that continued throughout the week.

Teachers reflected a wide range of responses when asked at the end of the week what they had gained from attending the Institute. One teacher talked about validation for her work focused on equity,

> *They [the teachers] echoed and validated the importance of the work I do—empowering the marginalized [students] to aspire to the top through hard work and taking action to mitigate the pronounced effects of climate change in their communities. (Veronica)*

Another resolved to infuse her conversations, action and curriculum with a stronger focus on climate and equity,

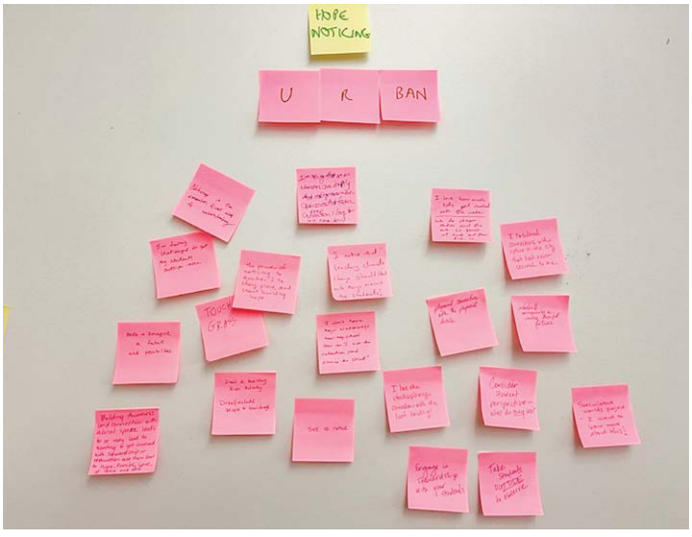
> *This Institute was different than any other professional learning experience. A new goal that I now have is to continue the climate and equity conversation as I go forward and participate with other groups. For example, I am looking forward to attending the state STEM Institute and visiting with other teachers about climate and equity curriculum. After this week, I am really interested to see what others in my state are doing. (Beth)*

Another important equity focus was addressed by three returning fellows: Abe Cohen-Garcia (‘22), Kelli Grabowski (‘23) and Jen Keller (‘23). Each respectively led a session on climate and equity from the point of view of urban, suburban, and rural settings. A teacher expressed the importance of seeing the connections across these landscapes as follows,

> *I appreciate how you categorized the sessions into Urban, Suburban, and Rural. Observing the challenges faced by teachers in different locations helps me analyze the equity issue across the US. Where a student lives and attends school affects the resources available to them, including the quality of teachers and available learning materials, as well as their interactions with the natural environment in their communities. (Agnes)*

With respect to equity, a teacher commented on two of the returning fellow’s sessions in a post-institute survey,

> *I found Diana’s framework around social justice: personal, instructional, institutional, systemic, to be helpful for examining dilemmas around equity, and was inspired by her model of thinking outside the box... Likewise Jen’s...naming of intergenerational equity affirmed my thoughts around our students and how they are the inheritors of generations of societal ills as well as environmental crises. (Evelyn)*



Teacher responses to hearing comments from a past Fellow about opportunities and challenges of teaching in an urban context.

Pedagogy

Three elements of the pedagogy component that are stressed in the institute include the need to acknowledge student anxiety, the importance of connecting/re-connecting with nature, and empowering students to take action to help combat anxiety and feelings of despair and powerlessness.

Acknowledging anxiety

Dr. Susanne Moser, a renowned climate scientist known for her research addressing the human dimensions of climate change, and on climate change communication, convened two powerful sessions on the emotional and psychological challenges of teaching and learning about climate change, often layered on top of emotional challenges and traumas students have already experienced. As in prior years, these sessions with Dr. Moser had significant impact on the teachers. Three teachers described their responses to her sessions,

> *I was profoundly affected by Dr. Susi Moser's session. Despite my 16 years of teaching science, I have never before addressed the emotional toll and sense of helplessness that students may experience when exploring how humans have altered or influenced changes in Earth's systems... The institute will have specific effects on what or how I teach... I will address climate data, emotions, healing, and love. (Beth)*
>
> *It will certainly make me more mindful. I am always mindful of student trauma and climate anxiety, but I feel far more aware of how the two are intertwined. (Sam)*

Dr. Susanne Moser is Director and Principal Researcher of Susanne Moser Research & Consulting in Hadley, Massachusetts, the unceded territory of the Nipmuc and Pocumtuc. She also is a Research Faculty in the Environmental Studies Department at Antioch University, New England. She is a research scientist whose work focuses on equitable adaptation and transformation in the face of climate change and interlocking stresses. She is a geographer by training with an interest in how social science can inform society's responses to the existential challenges arising from the climate crisis.

Connecting with nature

> *I have taught Climate Change in the past without taking into consideration the trauma the students may be going through. [This week] I have learned to consider options for students to express what they feel and suggest strategies to minimize stress. (Veronica)*

Connecting with nature

We emphasized the importance of connecting with nature when teaching about climate change and engaged teachers in multi-disciplinary ways with nature themselves. We took a guided walk through the Maine coastal forest and onto the rocky seashore, led by Schoodic ecologist Dr. Chris Nadeau. We highlighted the importance of narrative by spending an evening telling stories of the wonder and delight we have personally experienced in nature.

> *I am going to get my students outside regularly so they can sit in nature, touch grass, and observe the changes that happen around them. (Clara)*

We also immersed ourselves in "Place" by sketching the seaside landscape, led by renowned plein air landscape artist, Jill Hoy.

Sketching the landscape

Taking action

The strategy of empowering students to take action as an antidote to climate anxiety was exemplified by a student panel, brought to the institute by Margo Murphy, a 2022 fellow. The six students talked about climate actions they are taking in their Maine school and community for example, fundraising for a school wind turbine, educating elementary students about food waste and composting, and learning how to be able to influence change in the community. They dazzled the teachers with both their energy conservation actions and their lobbying the state legislature, as well as their articulateness and sense of empowerment.

> *The panel with Margo's students was a big highlight for me—my school has a small "Green Team", and seeing the dedication and enthusiasm of her students started a LOT of wheels turning in my head about how to move my own students to a higher level of involvement. (Owen)*

Bringing it all together

Starting midway through the institute, teachers began working to process the first three days' experiences in relation to their own practice, launched by Kirstin Milks, a 2022 fellow. In small groups they imagined and planned how their teaching and their collaborations could change in the coming year. They all saw the community among the Fellows as a key source of inspiration and support for their efforts. Ideas included place-based, project-based activities like native plant gardening in light of indigenous knowledge; long-term student research and action to "green" their school; presenting workshops about climate and equity for colleagues; and development of more interdisciplinary curriculum and teaching. Teachers also imagined some next steps in their own professional development paths, as teacher leaders. Teachers expressed their excitement about taking their experience home with them. For example, two teachers commented,

> *I am also excited to attempt to collaborate with other disciplines, specifically language arts and civics. I have tried this in the past, but now have some more concrete ideas that I can approach them with, such as activities related to place based projects and literacy activities. (Beth)*
>
> *I actually intend to lead my own PD on the subject... I will also steal lessons from everyone else [at the Institute] and am happy to have contacts to work with. (Sam)*

Finding inspiration

Continuing the work

All three cohorts of Fellows will continue to meet during the coming year. In a first zoom meeting, the first and second cohorts will meet their third cohort colleagues. Teachers have expressed their appreciation for the opportunity to continue hearing from each other and continue to gain inspiration and encouragement from hearing what other Fellows are doing.

Three of the first Fellows had an article recently published in the Knowles Foundation's *Kaleidoscope*. It is a significant contribution to the development of "best practices" for climate and equity education. https://t.ly/CsIZx

Closing statement

We have tried to design this institute to reflect TERC's best principles of professional learning—seeing learning as a socio-cultural process deeply engaged with scientific and social phenomena, and fundamentally an inquiry that includes investigation, action, expression, and reflection in a complex and dynamic mix. Our teachers and all our other colleagues have brought this vision to life in their own way over the past three summers. As one teacher described it,

> *Participation in this institute has supported my goals for my professional learning. My professional learning goals before the institute were to engage with educators with diverse experiences, foster authentic partnerships, deepen science learning, and liberate trauma. My needs were to identify points of light, leverage my influence, co-learning/co-teaching, and foster the hopes and dreams of my community. The institute has set a framework for my work and an opportunity to grow and sustain a reaffirming science and learning community through authentic partnerships. (Candace)*

Applications for the 2025 institute will open in January 2025.

Acknowledgements

We are grateful to the John D. and Catherine T. MacArthur Foundation for supporting this experiment in design, learning, and action.

We thank the teachers and our colleagues Folashadé Solomon and Annie Sussman, all of whom have been integral to this work.

Bios

Gillian Puttick is a Senior Scientist at TERC. She focuses most of her efforts on climate change education, addressing it from a biocomplexity and systems perspective, stressing the myriad socio-ecological interactions of life and environment.

Brian Drayton, a plant ecologist, is a Senior Scientist at TERC. Since 1989, much of. his work at TERC with teachers and curriculum has dealt with climate change ecology and its human dimensions.

The Schoodic seashore

Innovate to Mitigate

The Impact of Social Media on Green Roofs

O'NEILL COOPER AND ANNIKA ADAMO

Since 2019 TERC's national **Innovate to Mitigate** competition has engaged more than 160 student teams in Grades 8–12 to help build and design solutions to limit the impacts of climate change. This competition takes a project-based learning approach that supports student teams to investigate what causes climate change and then propose a solution that can help mitigate its effects. Students then crowdsource their proposals to other participants for feedback to help strengthen their approach. Each team works to develop a prototype, and at the end they dive deeper into the science when they and their peers discuss their final submissions online.

Green Roof Initiative

Team leaders O'Neill Cooper and Annika Adamo, whose Miami, Florida–based Project Green Roof (instagram.com/projectgreenroof) won second prize in the competition this year, describe their experience in the competition and how they utilized social media.
terc.edu/innovatetomitigate

Figure 1: The semi-intensive and intensive green roof models used in the experiment.

For our project, we decided to create a social media page that would aim to spread awareness about green roofs as a way to mitigate climate change. Green roofs, sometimes referred to as living roofs, are roofs that have a growing medium and vegetation built on top of a structure. Not only do green roofs offer a plethora of benefits, but they are also widely applicable, only needing a sufficiently strong foundation to support them.

Green roofs sequester carbon dioxide emissions through their plants and soil. As the plants grow, they use carbon dioxide as fuel and store it within themselves and the soil, locking it out of the atmosphere, where it would otherwise harm the planet by increasing global warming. On top of that, green roofs can heavily mitigate stormwater runoff that often harms local ecosystems. They do this by trapping the rainwater in the roofs' growing medium (soil) and then filtering out and absorbing any toxic particles before slowly re-releasing the now cleaned water. Green roofs also help the environment by serving as a place for native plants and animals to reside, thus increasing biodiversity.

In addition to environmental benefits, green roofs provide advantages for people's health and wallets. The growing medium, especially when saturated, acts as an incredible insulator, having been found to reduce the temperature of some buildings by up to 10 degrees Fahrenheit, or about 12 degrees Celsius. This reduces the need for cooling, which brings down the electricity bill. Furthermore, the plants perform evapotranspiration, the process of releasing water vapor through their leaves, which cools down the surrounding area. Not only will this cool down a building, but it can also combat urban heat islands, over-paved areas that absorb a lot of heat without any way of releasing it, resulting in that area being hotter than its surroundings. Heat islands pose a very large and possibly lethal threat to people, especially those who are vulnerable to heat-based illnesses. According to the EPA, urban heat islands can cause general discomfort, respiratory difficulties, heat cramps, heat exhaustion, and heat stroke.

Many people remain unaware of the innumerable benefits provided by green roofs, which we recognized as a challenge to their implementation. Seeing the need to spread awareness about green roofs in order for them to be widely adopted, we decided to utilize social media (in our case, Instagram), because it has become one of, if not the, largest and most effective platforms for quickly spreading information to a large group of people.

For the duration of the research period, we created and posted concise, single-image posts to teach viewers about a variety of topics relating to green roofs. In these posts, the team also discussed and monitored an experiment using the model

shown above (**Figure 1**) to test the ideal extensive green roof for South Florida. To gauge the effectiveness of our social media page, we created a survey that asked people a variety of questions concerning the page and how it affected their perception of green roofs.

The Project Green Roof team was able to survey around 150 people and, after compiling and interpreting their responses, we were able to confirm that our social media page was a success and that social media is an extremely effective tool for promoting green roofs. Fifty-nine percent of people had no idea what a green roof was before the post, while the other 41 percent had varying levels of knowledge on green roofs, although it was often a very surface-level understanding. After viewing the social media page, more than 90 percent of respondents said that the post had effectively taught them about green roofs. Of those people, 67 percent felt motivated to do more research and 80 percent said that they believed green roofs were applicable for their city. Overall, social media greatly boosted people's perceptions of green roofs, with the social media page causing people to be much more passionate about green roofs by teaching them about green roofs and their applications.

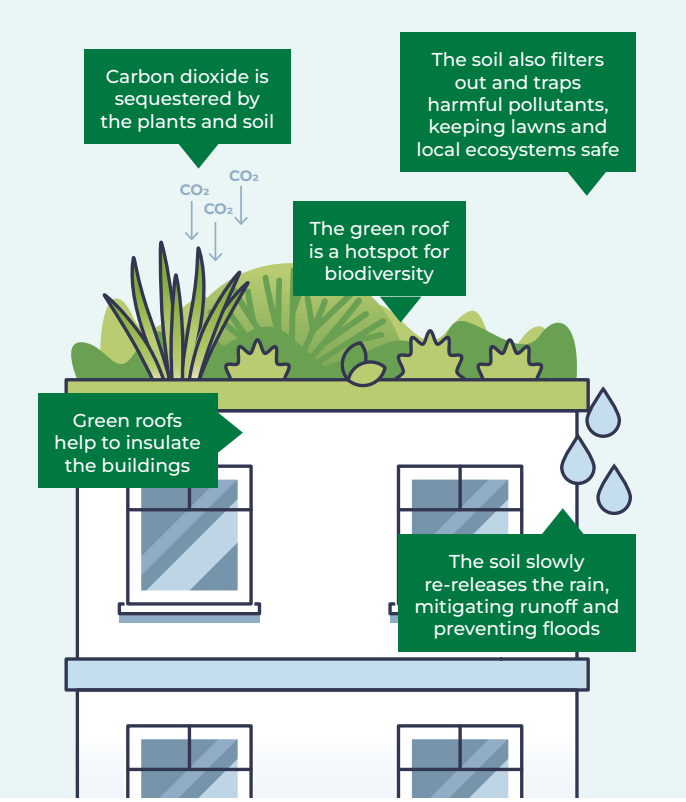


Figure 2: This is a diagram depicting the benefits of a green roof.

While the social media page was a resounding success, we also found room for improvement. Viewers' feedback mentioned that they felt the posts were "boring" or poor at capturing their attention. To solve this issue, we believe that the implementation of video-based content would be more effective at capturing an audience and boosting interest in the information on the post. Viewers also shared that they would not have likely seen the content had it not been personally promoted to them by the team. Video-based content would also be more likely to gain more traction, increasing the number of viewers and amount of information they are likely to retain. Higher viewer counts and retention rates will increase the effectiveness of the social media page, thus giving us a larger platform to educate on green roofs.

Some of us will be continuing our work researching and spreading awareness about green roofs on the social media page "Green Roof Initiative." We will be implementing the changes described above in order to make the social media page more effective. Moreover, we will be creating accounts on YouTube and Facebook in addition to an Instagram page, all under the "Green Roof Initiative" name, so that we can reach a wider audience.

BIOS

O'Neill Cooper is a high school junior in Miami with a lifelong passion for nature and environmental science. His fascination with nature has evolved into a commitment to sustainability, especially through sustainable architecture like green roofs. O'Neill aspires to pursue a career in environmental policy to drive impactful changes. When he's not working on his own projects or school, he loves volunteering at local parks and cooking. His goal is to merge his love for nature with a career dedicated to making a better world for tomorrow.

Annika Adamo was a member of the first-place *Innovate to Mitigate* team in 2023. This year she has also joined the Green Roof Initiative team. She is originally from Atlanta, and now lives in Miami, and was first exposed to green roofs in the form of a sod-roofed house at an open-air museum in Kristiansand, Norway. Annika's interest in the subject has only grown since participating in this project and she cannot wait to continue with more work.

ACKNOWLEDGMENTS

Thanks to our AP Environmental Science teacher, Pamela Shlachtman, for inspiring and teaching us about science and introducing the team to *Innovate to Mitigate*.

Using **MATH** to Connect Intergenerational Museum Visitors with **ART**

NURIA JAUMOT-PASCUAL, PH.D.

Art museum educators are always looking for ways to connect visitors with their museums and the art they house. Integrating math into museum activities turned out to be one way of sparking those connections.

Figure 1 | Gio Ponti guided tour.

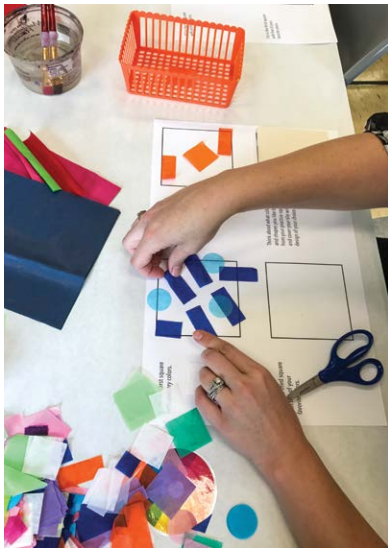


Figure 2 | Ponti-inspired tissue collage.

Figure 3 | Pattern on two chairs.

The InterGenerational ArtMath at the Museum (IGAMM) project brought together 15 grandparents and their 27 grandchildren, art museum education curators, and me, a TERC researcher, to explore the connections between math and art at the Georgia Museum of Art at the University of Georgia. The project consisted of six intergenerational sessions that promoted looking closely at the art by integrating math into art museum activities. These educational activities spanned different formats typical at art museums, such as family events, gallery activities, self-directed tours, guided tours, and classroom activities.

IGAMM activities were developed in a couple of ways. Sometimes, they evolved through the education curators and me visiting the galleries and talking about the math connections that we could see in the art. We then brainstormed about what kind of materials and activities would engage visitors in using those connections. For example, when the museum had a temporary exhibition of Gio Ponti's art, his use of patterns and geometric shapes offered a perfect math conversation piece in guided tours (**Figure 1**). They also helped spark grandparents' and grandchildren's creativity when working on tissue collages (**Figure 2**).

Other times, we started from the educational materials and then thought about what artwork might connect well with them. For instance, when I brought pattern blocks in for consideration, the education curators immediately thought that working with them would be a great gallery activity and were excited to find that their decorative arts collection had two chairs with a beautiful blue and red pattern that was a perfect connection with the pattern blocks (**Figure 3** and **Figure 7**). This idea turned into a gallery activity during a family day that directed visitors to find patterns on the chairs, observe what repeated and what changed, identify shapes, and create their own patterns using the blocks.

This article examines the main takeaways from two conversations that I had with the art museum's education curators, who I will call Aspen and Fern. The first conversation, at the end of the program, involved reflecting on finishing the project. The second conversation, which took place two years later, involved a discussion of the lessons learned that they had integrated into their ongoing practice.

Goals of Math in the Art Museum

The education curators explained that one of the main goals for bringing math into the art museum was for it to act as a bridge to help visitors make connections between the art and what they know from outside the museum. Aspen explained that, in one of the events, she observed a boy using pattern blocks to create patterns (**Figure 4**). She noted:

> "[I was] thinking about [this boy] and his connection to that part of the [pattern blocks] project and how for him that kind of math connection, breaking it down in that way can help bridge that gap. If you sit them down in front of a work of art and ask them what they think it means right off the bat, then that's a little bit harder of a leap. But if you can scaffold that by bringing in these other things that they're already familiar with, that are easier for them to connect to because of what they're learning in school, then that can help get them started."

Math contributed to the education curators' goal of building visitors' visual and museum literacy by encouraging them to look closer at the art and feel comfortable in a museum.

Figure 4 | Playing with pattern blocks.

Figure 5 | Exploring materials.

Affordances of Math in the Art Museum

The education curators pointed out that the processes involved in art are similar to those involved in STEM, such as observation, experimentation, and adjusting according to results (**Figure 5**). Fern observed:

> "The same way that scientists would conduct an experiment—you come in with this idea, you run some trials, maybe things don't work out exactly how you want, and you adjust and create new hypotheses based on your new data—it's an interesting way to think about the creative process and the scientific method, and how those two are related. So, that's been something that we've been thinking a lot about and had a lot of fun with creating programming."

For Aspen and Fern, IGAMM was an opportunity to test ideas and consider how the artistic and scientific processes could be integrated in activities and to fine-tune those activities by trying them with different groups. They noted that it is hard to find activities that work for different ages and that can be tied into multiple exhibitions, so IGAMM events were great opportunities to test activities. Aspen explained that using tissue collage tiles (**Figure 6**):

> ". . . was a great project. . . . It's not always easy to find projects that can be adapted and can be used by lots of different ages, and everyone enjoys, and that can . . . be adjusted . . . but the result is still satisfying, even if it's a three-year-old just dumping colors on there, and it still looks good. And it can be inspired by a lot of different exhibitions that can tie into this art activity."

Fern and Aspen also found that teachers currently ask for more interdisciplinary connections in museum activities in order to justify trips to the art museum with their class. Teachers need to demonstrate to their principals that children are working on education standards while at the museum; the IGAMM activities were an ideal way to accomplish these interdisciplinary goals.

Challenges of Math in the Art Museum

Fern, Aspen, and I agreed that it was challenging to bring together the goals of museum educators and researchers. Conducting research as initially planned would have been disruptive for Fern and Aspen. Given that the intention of the program was to integrate math as seamlessly as possible into museum activities, we found ways to make things work, but tensions occasionally arose. For example, from the museum educators' perspective, to design activities for the art museum that insert math, one needs to start from the work of art, not from a math concept on which one may want to focus. They felt that trying to impose a math idea on an art piece is artificial. Aspen explained:

> "That was the biggest challenge for me: how to find works of art that we can bring in the math or STEM connection and have it really be integrated in a way that is meaningful and satisfying for the people participating in it and ultimately helps people connect to the art. Because, for us, it's object-based, we're all about [working] off the work of art."

Another challenge was my interest in observing learning. Fern and Aspen considered trying to observe learning to be a traditional or school-like understanding of learning. The kind of learning happening in a museum, however, is related to engagement and making connections, which are not easily observable. This meant that some research activities, such as using a rubric to observe activities, were experienced as disruptive by Fern and Aspen. The lesson for me was that rubric data did not help understand museum learning, so the project would have benefited from a more authentically museum-based understanding of learning.

Other challenges were related to the nature of work in an art museum. As we considered activities for IGAMM, I learned that one needs to carefully consider where materials will be used, such as the galleries or a classroom. Materials for gallery activities need to be safe for the artwork. Materials that could destroy the artwork—such as paint and scissors—can only be used in classrooms. I also learned that there is some unpredictability in what art is going to be in the galleries, even when it is part of the permanent collection. Art can be removed from galleries at any point for a variety of reasons, such as being loaned out or being restored. Thus, museum educators need to be ready to pivot at any point.

After the project concluded, Aspen and Fern have continued using IGAMM activities and have found other opportunities to bring STEM content to the museum, including bringing together scientists and artists to the museum for a conversation on the ways their work overlaps.

Bio

Dr. Nuria Jaumot-Pascual is a Research Scientist at TERC. She currently co-leads four National Science Foundation–funded projects, which include: Native STEM Portraits, a longitudinal study of the experiences of Native students and professionals in STEM; the Institute for Meta-Synthesis, a project that has developed a series of modules to teach qualitative meta-synthesis methods to scholars focusing on equity in STEM; African American Young Women in Making to Engage in STEM and Entrepreneurship (AAMASE), a project that engages middle-and high-school African American girls through participatory design research in making and entrepreneurship activities emphasizing STEM disciplinary practices; and Afterschool Making Projects with Design Thinking and Mathematics with Latinx Communities (AMPD4Math), a project that engages middle-school Latinx youth through afterschool making projects emphasizing math and community. She is also co-PI for the Leveraging the AISES Archival Database study funded by the Spencer Foundation. Dr. Jaumot-Pascual is a member of the research advisory board for the ADVANCE Resource and Coordination (ARC) Network and holds a doctorate in Qualitative Research and Evaluation Methodologies from the University of Georgia.

Acknowledgments

I want to thank the grandparents and grandchildren who participated in the project, the education curators at the Georgia Museum of Art at the University of Georgia, and the Grandparents Raising Grandchildren Program at the Athens Community Council on Aging for their patience and cheerful engagement with this project. I also want to thank the Education Research Collaborative (ERC) at TERC for the generous funding for this project.

Figure 6 | Tissue collage tiles.

Figure 7 | Finding math connections.

Virtual Coaching *to* *Visualize Teaching*

Reflections of a Virtual Math Coach

KATHRYN HABIB AND CHRISTINA SILVA

Introduction: The Visualize Teaching Study

Teachers need ongoing opportunities to learn ways to improve their teaching. Professional development (PD) aimed at meeting this need has taken different forms but has been a stable and ubiquitous feature of the education system (Hill, 2007). Content-focused instructional coaching has emerged in recent decades as a promising approach to improving the quality of teaching and supporting student learning.

While research suggests that coaching has a positive impact on instructional quality, the majority of evidence supporting its effectiveness comes from studies of literacy coaching, with less known about the effectiveness of math coaching (Kraft et al., 2018). To help fill this gap, TERC's Visualize Teaching (VisTe) study explores the use of math instructional coaching to help teachers incorporate math argumentation into their teaching. The VisTe team defines math argumentation as the process of finding the mathematical truth through generating cases, conjecturing, justifying, and concluding on the mathematical concept being explored (Knudsen et al., 2018).

Visualize Teaching
math argumentation and more

Visualize Teaching, also known as Strengthening Middle School Mathematical Argumentation through Teacher Coaching: Bridging from Professional Development to Classroom Practice, is the fourth in its series of National Science Foundation–funded work. This design-based research project investigates the effectiveness of a PD model created for middle school mathematics teachers and coaches which emphasizes math argumentation. It builds upon 15 years of mathematics education and PD research led by Teresa Lara-Meloy and Jennifer Knudsen. In this iteration of the project, the research team developed and implemented a week-long summer PD workshop for teachers and their coaches in grades 5 through 8. The PD focused on emphasizing how mathematical argumentation can be used to equitably teach students of diverse backgrounds. Over three summers (2021–2023), the project team provided PD to a total of forty middle school teachers and coaches across the United States.

In addition to participating in the summer institute, teachers and coaches were tasked to complete four coaching cycles that implemented math argumentation lessons into their classrooms over a school year. Each coaching cycle was a four-step process (see **Figure 1**) where teachers:

1. collaboratively visualized a math argumentation lesson with their coaches (i.e., talked through what students and teachers would do and say);
2. taught the lesson as it was discussed with their coach and recorded the lesson for future reflection;
3. watched the recorded lesson and individually reflected on the teacher moves and student moves; and
4. debriefed with the coach, in-person or virtually, on what they noticed in the recording, what they felt were successes of the lessons, and where they wanted to improve during the next coaching cycle.

Coaching interactions occurred exclusively before and after the lesson (Steps 1 and 4); no coaching took place during the lesson itself.

The Teacher–Coach Collaboration

I (Kathryn Habib) joined the study as an unconventional participant. During the 2022–2023 academic year, I was a graduate student in my second year of a doctoral program in education. Before that, I'd been a middle school math teacher. During my time in the classroom, I participated in the pilot phase of a separate TERC study. A member of the research team

Figure 1 | The VisTe four-step coaching cycle

with whom I had kept in touch, asked me to join the VisTe study to act as a virtual coach to support teachers if their onsite coach could not meet with them.

I first met Thea and Lucy, a fifth-grade co-teaching team from a small rural school district in the northeastern U.S., during the summer institute for teachers and coaches preceding the 2022–2023 academic year. Thea was Lucy's special education teacher counterpart, providing additional support to students with specific learning needs. Initially, Thea and Lucy were working with a coach employed by their district, as was typical for participants in the VisTe study. However, the departure of their onsite coach mid-year created the need for a virtual coach.

The three of us then embarked on a teacher–coach relationship that was unique within the context of the VisTe study. First, because of its virtual nature. Second, because unlike the site-based coaches, many of whom had extensive teaching experience and between five and 10 years of coaching experience, I had only taught for three years before leaving the classroom to pursue a Ph.D. and had no prior coaching experience.

Navigating Virtual Coaching

While coaching virtually presented some predictable challenges, it also revealed unexpected opportunities. I was geographically removed from Thea and Lucy's school community, so, unlike the other teachers and coaches involved in the study, who met in person to plan and debrief lessons, as well as interacting informally throughout the school day, my interactions with Thea and Lucy were confined to Zoom.

This limited my ability to contextualize Thea and Lucy's teaching within the day-to-day goings on at the school and in the community. However, not being physically present in the building had its advantages: since I could not engage in administrative tasks or work directly with students, I was able to focus my efforts on helping Thea and Lucy unpack and refine their practice as teachers.

Research suggests that coaches' daily work can vary considerably across contexts (Mudzimiri et al., 2014) and often includes attending to administrative and logistical priorities in addition to working directly with teachers to support teacher learning (Campbell & Griffin, 2017). The time coaches spend advancing district priorities, managing student data, and supporting the day-to-day functioning of the school can limit their ability to focus on teacher learning and can undermine the teacher–coach relationship, as it detracts from the time spent working one-on-one together (Walpole & Blamey, 2008). Evidence suggests that when coaches spend more of their time working directly with teachers, this benefits both the teacher–coach relationship and student learning outcomes (Bean et al., 2010; Harbour et al., 2021). In our experience, virtual coaching acted as a natural barrier against the demands that can compete with coaches' work directly with teachers. Despite my limited knowledge of the local context and the challenge of establishing rapport through Zoom, Thea, Lucy, and I built a productive teacher–coach relationship.

Another benefit of not being physically present in Thea and Lucy's school had to do with the way teachers perceive coaches' positioning within the traditional school hierarchy. Although a coach's role is typically non-evaluative, coaches often work closely with administrators to advance school and district goals. When teachers view coaches as administrative agents, this can undermine the teacher–coach relationship and inhibit teachers' willingness to take pedagogical risks (West, 2009).

In contrast, coaching that attends to teachers' individual needs as learners has been shown to support teacher learning toward more effective instructional practices (Cross Francis et al., 2023). Given that I was not on site, regularly interacting with administration, nor was I employed by Thea and Lucy's district, they didn't perceive me as having any formal authority. This contributed to a collaborative environment in which they felt comfortable trying out new approaches to teaching math.

For example, one of the main goals of the VisTe project is to support teachers in facilitating student-led discourse, which can be a challenge because it gives students more control over the lesson. During several of our discussions, Thea, Lucy, and I talked about the obstacles they felt got in the way of student-to-student discourse, as well as its importance to student learning. Following our conversations, Thea and Lucy felt more comfortable taking risks to incorporate more and longer opportunities for students to work on math tasks in groups and to invite more student participation in whole-class discussions.

The Role of Classroom Experience in Coaching

At the start of the study, I was concerned about how my relative lack of classroom teaching experience would impact my ability to support Thea and Lucy's learning and our teacher–coach relationship. Research suggests that teachers with extensive experience may, at times, exhibit greater resistance toward coaching (Jacobs et al., 2018). Furthermore, I had never worked as a coach, though I had been coached during my time in the classroom and was engaged in research on coaching as a doctoral student. Despite evidence that deficits in expertise need not function as a barrier to improving teaching through coaching, and that when coaches adopt an inquiry stance toward instruction, it can even be an asset (Wilder, 2014), I wondered if I would have anything valuable to offer to two highly experienced teachers.

All these factors led me to approach my coaching role with the mindset of a learner. As it turned out, several advantages emerged from this dynamic. It established Thea and Lucy as the authorities on their own teaching, while I served as a mirror, helping them see parts of their practice with fresh eyes.

My work as a doctoral student allowed me to bring ideas from the research I was learning about into our coaching conversations. In one planning session, we talked about the deep and flexible knowledge of mathematical concepts teachers must have in order to interpret and respond to students' evolving understandings, a specialized form of knowledge conceptualized as Mathematical Knowledge for Teaching (MKT; Loewenberg Ball et al., 2008). Thea and Lucy enjoyed discussing what researchers are learning about the nature of the mathematical knowledge that underpins their everyday teaching practices.

Conclusion

Despite the challenges posed by our unique circumstances, I believe that our triad was a success. We learned a great deal from each other, and we developed a strong sense of community. This contributed to a positive and supportive learning environment that helped Thea and Lucy refine their practice as teachers and helped me grow as a coach. I am grateful for the opportunity to have been a part of the VisTe study and hope that our experience will provide valuable insights for other teachers and coaches who are working together to improve student learning.

Given my positive experience with participating in this research project and utilizing the Visualize Teaching PD model, I recommend that other schools consider integrating this model into their PD plan. For more information about how to access these materials, please contact: teresa_lara-meloy@terc.edu.

A final note concerns the relationship between teachers and researchers. While there has long been a tension between education research and practice, my experience working with TERC researchers as both a teacher and a coach was overwhelmingly positive. The research team actively sought feedback from teachers and coaches (e.g., through daily surveys during the summer workshop and during regular check-ins over Zoom throughout the school year) and incorporated participants' suggestions into the study's design. This, along with their availability and responsiveness, made me and the teachers I worked with feel that our ideas were valued and respected, creating a relationship of trust and mutual understanding between teachers and researchers, essential for bridging the gap between education research and practice.

Recommendations

The following recommendations may be useful for school administrators and practitioners who work with middle school math teachers.

Consider employing virtual coaches who are external to the school. This type of role facilitates a focus on coaches' interactions with teachers, rather than with administrators, and builds a relationship of trust that helps teachers feel more comfortable taking pedagogical risks. In cases where coaches are district-employed and/or site-based, position coaches as supporters and advocates of teacher learning, rather than as evaluators or administrative agents.

Consider having pairs of teachers work with a coach together, particularly if they co-teach. Thea and Lucy each had unique perspectives on their shared group of students and what teaching approaches and strategies might best support their learning. This expanded the insights that emerged from our joint coaching sessions. Evidence supports the idea that this kind of teacher co-learning bodes well for improving instruction (Avalos, 2011).

Consider prioritizing coaching tasks and excluding managerial tasks (e.g., handling student data) from coaches' workload. Protecting time for coaches to engage in full coaching cycles with teachers enhances the effectiveness of coaching (Saclarides & Lubienski, 2020).

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