Creating A Curious Classroom Using Science And Engineering Practices

Introduction

I (Meenakshi) have had the privilege of working with K–12 science teachers for almost a decade. Every now and then, I have the pleasure of interacting with a science teacher who leaves me feeling inspired and motivated. One such teacher was Matt, who was my graduate student completing a STEM endorsement program. Matt had just completed planning, enacting, and reflecting on his mini-units, which were part of his program requirements. The goal of this work was to design and implement phenomenon-based units grounded in science and engineering practices (SEPs) to support student sense-making (NRC, 2012; Bybee, 2008).

In reflecting on implementing his mini-units, Matt shared how they helped him get in touch with his own curious self. He shared that he felt a deep sense of curiosity about the natural world since childhood, and that curiosity still motivates him as a science teacher. He was enthusiastic about the notion of curiosity and its role in the classroom.

Curiosity is at the center of the three-dimensional, phenomenon-based science instruction introduced by “A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas” (NRC, 2012) and central to the structure of the Next Generation Science Standards (NGSS). Matt’s planning and classroom instruction was an effort to meet the visions of this framework.

Together, Matt and I decided to share the story of Matt's sixth-grade classroom with other science educators to help support their curiosity during the different stages of planning, enacting and reflecting.

First, Matt shares a narrative of his journey as a curious learner: experiences he had along the way that shaped his understanding of curiosity, the challenges and encouragements his curious self faced, and contexts and actions that sustained and promoted his curiosity.

In the second section, we share the learning we engaged in together through analysis of and reflection on Matt's practice. We offer lessons and teaching strategies that foster and maintain curiosity among both students and teachers.

Part 1: Curious Matt

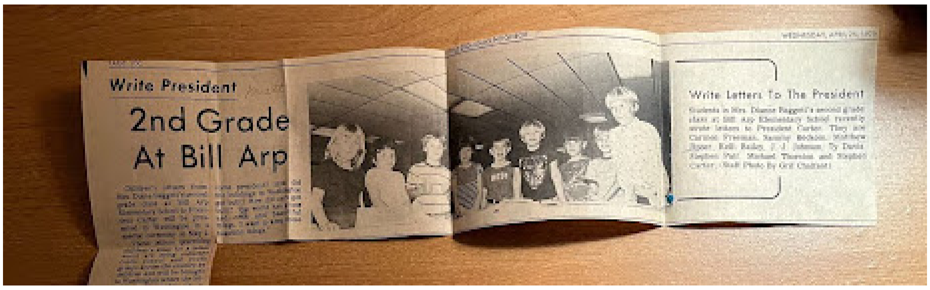
I (Matt) have always been a nature lover and a curious being. Growing up, I would often explore the natural world and take journeys marked by inquisitiveness. When I got bored at home, I would go outside to observe birds, trees, bugs, the wind, unfamiliar sights and smells, clouds, and my favorite natural phenomenon: the sound of rustling leaves. I remember mimicking the animals of the forest while drinking pure, clear water from the natural springs of Rocky Creek, slurping and savoring every drop. I particularly enjoyed investigating the different shapes, sizes, textures, and patterns of the rocks, and the crawdads and fish that lived in the creek.

In second grade, I wrote a letter that was presented to President Jimmy Carter. In my letter, I asked curious questions—"How did you become president?" "How did the buildings in Washington get built?" "How did cars get built?—and shared a wish: "The world has grass and rock and beautiful things. I want to keep these beautiful things" (Figure 1). Later, I begged my mother to buy me a microscope from Sears and Roebuck, which I still have and use to this day (Figure 2). These artifacts remind me of my childhood curiosity, my nature of asking questions and my drive to explore the world around me.

As a teacher, I realize that my students also come to my classroom with such curiosity. I can use their curiosity as a tool to involve them in science and *encourage them to explore the world around them. I believe that by fostering their natural curiosity, I can help them become lifelong learners and critical thinkers.*

Figure 1

Letter to President Carter


Write President

2nd Grade At Bill Arp

Write Letters To The President

Note. I am the student with the “Fonzi” thumbs out, celebrating my letter to President Carter.

Figure 2

Childhood Microscope from Sears

Staying Curious: Challenges and Opportunities

As I began to enter my adolescent years, my curiosity for the natural world started to fade. Instead of looking outward, I began to focus inward in an effort to preserve myself. Ironically, as someone who found studying thunderstorms to be captivating, my own home situation was like a raging storm. I was fortunate to have a science teacher who noticed my struggles and used our shared interest in the comic series *Conan the Barbarian* to strike up a conversation, build a relationship, and reignite my interests. His act of kindness and compassion provided me with the support and tools I needed to express myself and continue to nurture my curiosity.

As I reflect on my past experiences as an adolescent, I cannot help but think about my current middle school students. This serves as a reminder of the importance of building relationships with my students, as it can provide insight into their interests and what makes them curious.

After high school, I enlisted in the Navy for four years and traveled to various countries such as Spain, Italy, Israel, and the Greek islands of Crete and Cyprus. The sights, sounds, and smells of these places always intrigued me, but it wasn't just the travel that sparked my curiosity—being on the sea also allowed me to observe natural phenomena on a regular basis. As I patrolled the weather decks, I was able to view a live planetarium show. The absence of light and pollution meant that sometimes the Milky Way would stretch across the sky as if I could touch it. I would stare at it, wondering if someone was looking back at me. During my time in the Navy, I also developed the skill of paying attention to detail, as it was a matter of life and death for myself and the crew.

Part 2: A Curious Classroom

As an educator of a sixth-grade Earth science class, I am aware of the unique challenges faced by my diverse student body. Many of my students come from moderate- to low-income families and represent various racial and ethnic minority groups. My students often experience instability in their home environments, which can shape their experiences in school and in my classroom. In science education, I can create a positive and empowering learning environment by moving away from memorization and towards a curriculum that leverages students' curiosity and interests and values their ideas. This approach can lead to the students’ deeper understanding of the subject matter and seeing themselves as capable learners.

Planning for a Curious Classroom

I was introduced to the idea of three-dimensional instruction as mentioned in the current science education framework (NRC, 2012). The framework advocates classroom science instruction that affords all students opportunities to learn and use scientific practices to investigate the natural world around them (NRC, 2012). By doing so, it centers curiosity throughout the teaching and learning process. During my STEM endorsement program, I was required to design and implement instruction that engaged students in scientific practices to investigate natural phenomena. I planned two mini-units that were grounded in phenomena and scientific practices (Table 1).

Table 1

Description of Mini-Unit One and Mini-Unit Two

	Mini-Unit One	***Mini-Unit Two***
Driving question/ Phenomena	**Why Does The Moon Change Shape?** **Moon Phases** *What patterns do you observe as you play the simulation and why?*	**Where Did The Rainwater Puddle Go?** **Evaporation** *What happened to the water in the puddle?* *How did it change to clouds?*
Focused SEP	*Engaging in Argument From Evidence*	*Developing and Using Models* *Engaging in Argument From Evidence*

Key activities	***Introducing the phenomenon****: Animation of moon going through its phases on a video loop and students working in small groups to offer their initial explanation for what they were observing using CER (claim-evidence-reasoning).* ***Simulation activity*** *Students analyzed a simulation of the Sun, Earth, and Moon system.*	***Introducing the phenomenon:*** *Students were given a graphic organizer with 2 different sized puddles and were asked to draw and explain the change in the size of the puddle.* ***Simulation activity*** *Students observed the simulation that showed the particle nature of matter.*

During the planning stage, I made sure to incorporate exploratory scenarios and questions that would spark my students’ curiosity. For our investigations, I selected everyday, relevant topics such as moon phases and the disappearance of a water puddle over time. To support their exploration, I focused on using scientific argumentation and modeling as key scientific practices. I designed learning activities that engaged students in “doing” the work of science. While planning, I asked myself questions such as, “How will these activities allow students to gather evidence to explain the phenomenon? What will my students be doing as they engage with the selected SEPs? How will students make sense of the data and observations that they will be collecting?” This helped me ensure that my instruction was fostering curiosity and critical thinking skills in my students. I also planned a few strategies, which I intended to implement during the enactment stage to encourage curiosity in my students. Together, my advisor Meenakshi and I considered the following approaches:

1. Using driving questions to launch the phenomena: I used driving questions and a driving question board (DQB) (Weizman, Shwartz, & Fortus, 2008), as well as other tools such as a Google Jamboard to inspire curiosity.

2. Supporting student collaboration: I planned to encourage students to share their ideas and evidence with their peers using DQB and Google Jamboard (Figure 3).

3. Leading by example: I planned to model my own curiosity by actively listening to

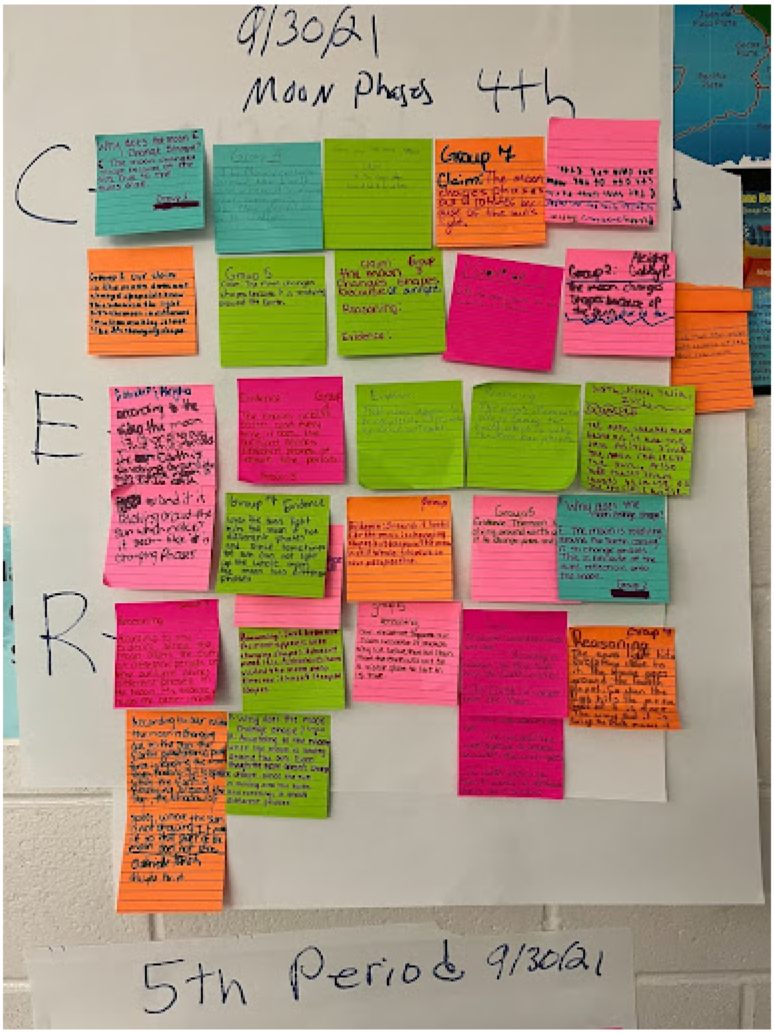
students and valuing their reasoning and explanations for the phenomenon.

4. Encouraging use of scientific practices: I planned to use scientific practices to encourage student sensemaking (Schwarz, Passmore, & Reiser, 2017).

5. Celebrating students' curiosity: I planned to consciously recognize and celebrate the successes and achievements of students, who are exploring and learning new things.

Figure 3

Driving Question Board



Note. Driving question board invites and shows the range of student curiosity in relation to everyday phenomena.

Implementing for a Curious Classroom

I implemented these units in my classroom and observed that my students were highly engaged and curious throughout the learning process. They were excited to collect data and make predictions about phenomena. They were also excited to share their findings with their peers and discuss their observations and conclusions. I analyzed my teaching videos from the mini-units to understand if and how I was leveraging my own and my students' curiosity while attempting science instruction grounded in the SEPs. It helped me reflect on my in-the-moment actions and if and how they had implications for creating a classroom culture that stimulates and nurtures curiosity.

Modeling Curiosity

I modeled curiosity by using various talk-moves, gestures, and intentional questioning during small and large group discussions. As the lesson progressed, I walked over to small groups and elicited their insights regarding the task they were doing. In the transcript below, I illustrate how I made intentional attempts to make productive teaching moves (Michaels & O'Connor, 2015). I've included reflections on how I was modeling curiosity in italics following my dialogue.

Teacher*:* What you got? *(I am interested.)*

Student*:* So our claim is, um, the molecules expanded and spread out when they heated up, slowed down came together when they were cold. *(using the language of claim-evidence-reasoning)*

Teacher*:* How did that change from your initial claim? *(I am interested to see how student thinking changed over time and how they are using evidence to support their claims.)*

Student*:* Well, our initial claim, we believe that the evaporation of water leads to condensation in the sky to form clouds, but in our revised claim we expanded the idea more and went into specifics.

Teacher*:* Aahhhh! *(My expression to signal that I am interested and curious in their reasoning.)* Did you add any more evidence? (*I am curious about how the idea evolved.)*

Student*:* Yes.

Teacher*:* What did you add? *(I am curious about how the idea evolved.)*

Student*:* The water vapor rises because of heat from the sun and condensed into clouds in the sky when they got colder.

Teacher*:* Okay, did you change your reasoning?

Student*:* Yeah. When the molecules heat up they turn to gas and when the molecules cool down, they revert back to a solid. *(The students' original reasoning was similar but not as specific as their revised reasoning.)*

The dialogue provided above shows that use of argumentation as a scientific practice (Reiser, Berland, & Kenyon, 2012) provided a structure to probe students for claims, evidence and reasonings and demonstrate my teacher-curiosity.

Actively listening also conveyed my teacher-curiosity. I allowed space and time for students to exchange ideas and at times stepped back and took the role of an active listener who provided curious affirmations.

Reflection on my teaching videos revealed instances of students' increasing curiosity about the phenomenon. For example, one student wonders whether the moon changes phases at a consistent rate throughout the year or if weather has anything to do with it. Another student demonstrated curiosity about the impact of the sun on evaporation.

Phenomenon-based instruction requires curiosity as a driving force, and there are concrete steps that can be taken during instruction to spark this curiosity in students.

To foster a classroom culture that centers curiosity, it is important to overcome conventional restraints commonly exercised in schools. A traditional classroom image of students sitting passively, listening to lectures, memorizing scientific facts, and following regimented steps and procedures stifles both student and teacher curiosity. Phenomenon-based instruction requires curiosity as a driving force, and there are concrete steps that can be taken during instruction to spark this curiosity in students.

Teacher Noticing

Teacher noticing is the ability to observe and identify important aspects of the classroom environment and connect them to broader educational principles or practices (van Es & Sherin, 2002). We (Meenakshi and Matt) analyzed teaching videos from mini-units one and two, specifically focusing on instances where I (Matt) was explicitly attending to students' ways of thinking as a manifestation of my teacher-curiosity. By analyzing my noticings (Table 2), we aimed to understand how my teacher-curiosity manifested in the classroom and how it influenced my instruction.

Table 2

Teacher Noticings During Mini-Units

Noticings about student learning	Noticings about Matt's teaching practice
● Students' reasoning and partial explanation about phenomena.	● Asking questions related to phenomena and the scientific practices—probing students for claims, evidence and their observations based on simulations.
● Students articulate their claims and evidence.	● Encouraging students to share ideas with each other.
● Students observe and follow up curiosities with questions.	● Providing space for new ideas related to the phenomena.
● Students use scientific vocabulary.	● Facilitating students' observations and data collection during investigations.
● Students use their own language as well as scientific vocabulary to try and explain phenomena.	● Asking students to note down their observations and data.
● Students use their everyday language and scientific vocabulary as needed to convey their understanding of NGSS 3D learning.	● Frequently reminding students to keep in mind the main question they were trying to answer and to stay focused on making sense of the concepts at hand.
● Students struggle to explain their scientific models.	
● Students recognize the importance of other groups' models as significant information to justify, revise, or argue over why their models are similar or different.	

Teacher noticings (listed in Table 2) matter for creating a classroom that centers curiosity. Such noticings serve as important cues for how investigations and the inquiry related to the phenomenon are unfolding. I was able to make many noticings about my classroom practice and identify pedagogical moves related to implementing SEPs and promoting curiosity. Hopefully, I can use such analysis to further inform and improve my teaching moves that promote curiosity.

Reflecting on a Curious Classroom

In the reflective stage, I analyzed my teaching videos and evaluated the effectiveness of the SEPs in supporting curiosity. I observed that the use of the DQB and Jamboard helped to spark students' curiosity and promote a culture of inquiry. I also noticed that the students were more engaged and motivated when they were able to ask their own questions and explore phenomena that were relevant to their everyday lives. Additionally, I noticed that the use of scientific argumentation and scientific modeling helped students to make sense of the data and observations they collected.

Video Reflections

Using my teaching videos, I was able to gauge the type of learning environment that existed in my classroom during the implementation of the mini-units grounded in SEPs. I used a set of descriptive markers to reflect on my teaching videos (Annexure 2). These markers guided me to identify teaching moments from the videos and further interpret them to make sense of my teaching in relation to SEPs. A holistic look at the kind and frequency of markers I used to analyze my videos gave me an approximate broader picture of the kind of learning environment that existed in my classroom.

When I analyzed the data it shows that out of all the teaching moments I noticed and interpreted, 10% of them were about students' questions and 20% were about providing evidence regarding how students were engaged in scientific practices. This analysis showed me what I was curious to know about my students' learning and my own teaching. It gave me a sense of the classroom culture I was creating for my students and what I was valuing and emphasizing in my teaching knowingly and unknowingly.

Such an examination allowed me to see the extent of opportunities I was creating to express curiosity by sharing questions, evidence, and explanations. Video markers helped me identify areas of improvement in my teaching. For instance, I wanted to see where I was challenged and the opportunities I missed to support students' curiosity. This reflective process provided invaluable insights that compelled me to rethink and adjust my teaching to align it to the vision of a classroom centered on curiosity.

Challenges

Although the curious classroom environment is stimulating and rewarding, there are many challenges to sustaining this charged atmosphere of excitement. The first challenge I noticed is that it can be exhausting to plan and sustain a curiosity-driven classroom. During the first day of the mini-units, the students and I were so engaged in the investigation; my adrenaline was ramped up and I was constantly moving around the room. I was worried about missing a moment of significance; anything inspiring could be lost forever and so my “spidey-sense” was always tingling. After the day ended, I went home drained and almost instantly fell asleep on the couch. I realized that having an authentic, relevant, and engaging scientific investigation with students was meaningful to me as a teacher, and that for it to be sustainable, I needed support from school administration and a community of collaborative teachers.

Another challenge I faced was a lack of resources and materials that were appropriate for my students’ backgrounds and experiences. This lack can make it difficult for students to connect with the content and can limit their curiosity. It is important for teachers to seek out and create resources and materials that are responsive and relevant to their students’ backgrounds and experiences in order to create a more inclusive and empowering learning environment. There are existing resources that can be leveraged for classroom use. I have included some examples in the resources section at the end.

It is also important to have a clear lesson plan and learning objectives, while allowing for deviation and spontaneity in order to capitalize on student curiosity and interest.

Last but not least, it can be difficult to balance the need for structure and organization within traditional forms of schooling with the freedom and flexibility that a curious classroom requires. A curious classroom can get noisy with all the excitement and student enthusiasm is sometimes carried into the hallway where they are supposed to be quiet as they transition from one class to the next. Clear expectations for behavior help students engage enthusiastically while working within the confines of the school’s structures. It is also important to have a clear lesson plan and learning objectives, while allowing for deviation and spontaneity in order to capitalize on student curiosity and interest. Finding the right balance can be difficult, but it is important to remember that student engagement and learning should be the ultimate goal. To address this challenge, it may be helpful to incorporate formative assessment techniques that allow for ongoing monitoring of how one is providing opportunities for student learning with curiosity as a primary impetus.

Closing Thoughts

It is important to reflect on our own curiosity as teachers and consider life experiences that can influence it. It was useful to get re-introduced to myself as curious Matt and share personal anecdotes recounting my curious nature and how it evolved. It helped me humanize my students’ life experiences, understand their curiosity and how to tap into it. In the process of analyzing my teaching videos, I recognized that students come to the classroom with different levels of curiosity and that this may be influenced by their background and experiences. I also realized that planning is the key to creating and sustaining a curious classroom environment. Teachers need time and space to reflect, plan and collaborate for such teaching. They need teaching resources that center on eliciting students’ ideas and positioning them as curious beings who are figuring out the natural world.

Annexure 1: Matt’s teaching video as example

Annexure 2: Descriptions of Markers used for video analysis

1. Teacher asking questions: Identify places in the video where you are asking questions. Think about the nature of your questions—are these questions helping facilitate students’ understanding of STEM and supporting their sense-making? How are these questions aligned with your use of the chosen SEPs, for instance, how are your questions supporting students’ thinking of an investigation or experimental data?

2. Student asking questions: What kind of exploratory questions are being asked by students? How is this specific SEP helping students ask questions?

3. Introducing SEPs: How are you introducing students to an SEP(s)within this activity in the video? Think about your task or activity here. How is this task or activity supportive of engaging students in an SEP?

4. Evidence of student engagement in SEPs: What evidence do you have, based on the video, that supports students’ engagement with an SEP(s)? There can be more than one piece of evidence. One example is you are helping students design an experiment and they are sharing some ideas with you.

5. Teaching SEPs: You are teaching SEPs—showing students examples of data collections, teaching claim-evidence-reasoning, making sense of graphs, etc.

6. Challenge in teachers use of SEPs: Identify challenges in your teaching practices and instructional strategies. What you consider a challenge is up to you.

7. Success in teachers using SEPs: Identify successes in your teaching practices and instructional strategies. What you consider a success is up to you.

8. Evidence of students’ understanding of SEPs: Refer to student work—their responses, work in small groups, etc. can be used as evidence of their understanding.

Resources

https://www.openscied.org/

https://www.nextgenstorylines.org/what-are-storylines

https://concord.org/

https://activatelearning.com/iqwst/

Dr. Meenakshi Sharma is an assistant professor of science education in the Tift College of Education. Her work centers around science teacher education and students’ learning of science in K–12 classrooms. She specifically focuses on inquiry-oriented science teaching, as aligned with the Next Generation Science Standards (NGSS) and STEM education. You can reach Meenakshi at sharma_m@mercer.edu.

Matthew C. Roper has been curious about the natural world around him ever since grade school. This natural curiosity was fueled by growing up in the woods behind his house, growing vegetables in the family field, and exploring the wilderness daily. He has always had a love of wanting to know the hows and whys of things, so science quickly became his passion. He now shares this passion as a middle school science teacher in Georgia, where students become their own teachers through their experiences in the natural world, driven by their curiosity. He likes to read and collect books and medieval artifacts, while spending time with his wife, four cats, and two turtles. You can reach Matthew at cryptiduniverse50@gmail.com.