

Examining and Interrogating Preservice Teachers' Conceptions of Science: An Anchor Activity to Support Preservice Science Teacher Learning

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Abstract

Efforts to expand who participates in science, both inside the classroom and beyond it, have been ongoing for many years with mixed results. Students who don't look, sound, participate, or learn like the traditional vision of the "good science student" are often left feeling like they can't be successful and/or that they do not belong. As with many science teacher educators, the barriers that prevent K-12 students from fully participating in science are items I seek to address in my work with preservice teachers. In this paper, I share an anchor activity that supports this work by helping middle and high school preservice science teachers first document and then build upon their conceptions of science and science participation over time during a science teaching methods course. The activity and subsequent conversations described in this paper are designed to open up space for preservice teachers to reflect upon different conceptions and experiences of science that their students will bring into their future classroom and how those relate to their own. It also provides opportunities for preservice teachers to interrogate their own conceptions of science in schools and start to build visions of science learning and participating that challenge the reproduction of climates, messages, and barriers that restrict science participation for many science students.

Introduction

Efforts to expand who participates in science, both inside the classroom and beyond it, have been ongoing for many years with mixed results (Calabrese Barton & Tan, 2020). Students who don't look, sound, participate, or learn like the traditional vision of the "good science student" are often left feeling like they can't be successful and/or that they don't belong (Segura et al., 2019). Similarly, students whose home cultures, ways of knowing, and prior experiences that don't align with the culture of science often feel invisible or less than when learning and participating in science (Bang et al., 2013). These impediments often have negative impacts on students' ability to pursue science-related futures, including pursuing science degrees, securing science related jobs/careers, and leveraging their science knowledge in their community and lives as citizens (NSF, 2021).

As with many science teacher educators, the barriers that prevent K-12 students from fully participating in science are items I seek to address in my work with middle and high school preservice teachers. Of course, I want preservice teachers to leave our science teaching

methods course more prepared to bring dynamic and consequential learning experiences to their future classrooms. There was a time when we spent the vast majority of our time and energy on this pursuit. However, as time as has gone on, I have grown to realize the type of science classroom that opens up opportunities for all students to be successful and feel like they belong requires more than just an understanding of pedagogy and a strong science content background. Instead, we must focus on helping preservice teachers build relationships and create the types of classroom environments that uncover and legitimize aspects of their future students as learners and people who have their own histories in science and school that are vital to how those students learn and participate (Greenberg et al., 2024). These relationships and environments afford preservice teachers opportunities to understand the students they will eventually teach did not experience science and school in the same ways they did – as such, they cannot solely rely on their own experiences and understandings of life in science classrooms to engage all of their future students.

Thus, each year, as I think about redesigning and teaching a methods course for prospective science teachers, I start by thinking about the diverse range of students that will be in their future classrooms. How do we best support future teachers in creating spaces for students who have traditionally not felt part of science? Who feel like they can't be successful? Who feel like or have been shown that they don't belong in the culture of science? The answers to these questions are complex and are something we explore throughout the course.

In order to start working toward addressing these questions and barriers, I have learned that I needed to start where preservice teachers are in terms of their current understanding and experience with science, school, and its intersection. This is not a new idea. Lortie's "Apprenticeship of Observation" (1975) helps us understand that much of how preservice teachers think about what science looks like in a classroom space comes from their prior experiences in that space as students. In other words, preservice teachers, often lacking experience in what else science teaching and learning can look like, revert to their experiences in classrooms to define what it can and oftentimes should be. Furthermore, they rely on a vision that was limited to their personal view from a student perspective that did not allow access to the complex nature of teaching or the diverse ways in which their peers were experiencing the science classroom (Lortie, 1975).

This idea of relying on their "apprenticeship of observation" is problematic for educating preservice teachers to transform classrooms to be more inclusive and welcoming for all science students. In particular, if preservice teachers reproduce the cycle of science teaching and learning they experienced, they are also likely reproducing climates, messages, and barriers that restrict science participation for students who are traditionally underrepresented in science and/or those students who come to the classroom believing science isn't for them based on past experiences (Bang et al., 2013). I do not want to prepare science teachers to reproduce the same outcomes over and over and instead aim to challenge them to design for their future classrooms to be inclusive and participatory.

In order to frame the course around this type of design for a science classroom, I have found a required aspect is to first bring forward and then continually interrogate preservice teachers' (and my own) definitions of science and what it looks like to participate in it both inside and outside of a classroom. This allows us to name, document, and then return to these conceptions throughout the course as new ideas and ways of thinking about science teaching are introduced. In order to do this, I utilize an anchor activity (Tomlinson, 2001) that is returned to frequently throughout the course. This anchor activity and the potential discussions it helps open up are the focus of this paper.

Context: A Science Methods Course

The year-long course in which this anchor activity and subsequent discussions take place is generally made up of juniors and seniors in our education program who are preparing to be middle or high school science teachers. The course is the only one in our program that is focused specifically on the methods of science teaching and is made up of only students who want to be science teachers. In general, the enrollment is somewhere between 10-20 students. These students have many opportunities to be in schools with K-12 students throughout their time in our program, but the particular course that is described here has no field component to it. The science methods course is centered around the following questions:

- What does it mean to learn and participate in science? How can we ensure that an expansive conception of science is represented in our students' learning experiences?
- What barriers do students encounter in attempting to participate in science? How do we ensure our classrooms are inclusive spaces where our students can participate and form science identities?
- How do we plan and carry out learning experiences that allow our students to draw upon their interests and experiences in ways that lead to engaging and meaningful science learning?

This is a course I designed with the input of others in our department, as well as mentorship from past colleagues and advisors along the way. I also draw on my experiences as a middle school science teacher, as well as designing and implementing informal STEM programs in multiple contexts. As such, while I strive to have these conversations be pre-service teacher-led, I also bring with me my own beliefs about science and the possibilities for what it can look like in classrooms. I believe that science can and should be consequential and meaningful for students. For me, this means that science is connected to the people, places, or phenomena that matter to students, that students have voice in both determining what/how science matters and the outcomes of learning science and that students should most often be positioned as active and not passive in those learning activities (Birmingham et al., 2017; Birmingham & Calabrese Barton, 2014). I believe this requires science teachers to not only recognize that students bring with them areas of expertise, experience, and

wonder that are vital to science learning and participation but also that space be made for students to see these areas legitimized or taken up in the classroom (Calabrese Barton, Tan, Birmingham, 2021; Birmingham et al., 2017).

In what follows, I first describe the anchor activity that I introduce at the beginning of our science methods course with preservice teachers. The anchor activity serves as a jumping-off point for us to think about and work toward addressing the potential issues and questions described above. It is often revisited throughout the course to ground conversations. After the overview of the activity, I next describe some of the ways in which this activity can be used to assist preservice teachers in learning about their students as well as investigating how they conceptualize science learning and participation. Please note this is one such activity that should be accompanied by ongoing efforts throughout the academic year to better understand students' relationships with science participation and learning.

Learning from student pictures and stories

Getting started: In this activity, preservice teachers are asked to choose and then share a picture of them participating and/or learning science in ways that matter to them. They are advised that they will be sharing this picture with the class and briefly describing how this represents them participating and/or learning science. The assignment prompt is left intentionally vague due to the desire to leave space for preservice teachers to make choices in connection to what science is, how/where they participate with science, and how it might matter to them. They can either email digital copies of pictures, submit them through a digital learning platform (i.e., Canvas), or bring in printed-out versions of their picture. Instructors should make sure technology is available for students who do not have access to the necessary technology needed to complete step one of this activity. I generally have students complete this activity at the beginning of the course, but it can be implemented at any point that you want to open up these conversations with your students.

Sharing stories: The next step of the activity happens in class and is focused on preservice teachers sharing their pictures and stories. As they come into class, they are met with two prompts for them to individually reflect upon and complete on their own. These are:

- *Science is:*
- *Participating in science looks like:*

Of course, these prompts can be modified for different contexts. However, I start with these because I want to activate their individual thinking around how we might define what learning and participating in science is. Completing this section of the activity individually provides time to elicit their initial ideas about these concepts that can be drawn upon in subsequent conversations and activities.

Next, we prepare to share our pictures and stories. I remind preservice teachers that when they see their picture displayed (I usually place pictures in a PowerPoint presentation for ease of sharing), they are asked to 1) share details about what this picture is showing us and 2) describe how this picture represents science participation that matters for them.

In addition to their individual stories, I ask the class to think about how these presentations tell a collective story about science and science participation. Thus, before the presentations begin, I ask the class as a whole to think about the following questions as they listen to and reflect upon their peers' stories:

- What patterns do you notice across the pictures and stories? What interesting outliers did you notice?
- What do these pictures and stories help you think about in connection to how we might define science? Or how we might define what it looks like to participate in science?
- How, if at all, do these experiences of your peers connect to yours? What specifically is the connection?

Next, each student has the opportunity to briefly describe their picture and story, with opportunities for peers and the teacher to ask questions afterward. As the instructor, I also make sure to share a picture and describe how it represents science participation for me.

Analyzing and synthesizing patterns – whole, small, individual: Next, as a whole group, we briefly discuss our initial reaction to the pictures and stories in relation to the questions I asked them to consider. Once we have this initial conversation, we transition to small group work to collectively build understandings of the following questions: What does science learning and participating look like for the members of our class? How does this help us build a definition of science? The small groups are asked to reflect on the patterns of science learning and participation they saw across the entire class. I push students to think about how science was defined, where science was happening, who it was happening with, and how participation in science was represented. The goal here is to develop a complex picture of what science learning and doing can look like based on the experiences that preservice teachers decided were important to them. Small groups record their definitions and thoughts on a poster that is then displayed on the walls of our classroom for further use and reflection. All groups walk around and review what each group came up with. This is followed by a whole class discussion of overlaps and differences in what each group came up with.

Finally, students are asked to individually look at what they wrote in response to the prompts – “*Science is*” and “*Participating in science looks like.*” They are asked to add to, modify, and reflect upon how their conceptions of learning and participating in science align or diverge from what their group and other groups came up with. Students are instructed to keep these as they will be revisited throughout the course. Additionally, the posters small groups created

are kept on the walls of the classroom and revisited/revised throughout the course. The public record of their thinking is vital to be able to reflect upon any transformations of how they define science and science participation.

Potential Conversations and Learning Opportunities that Build Off Anchor Activity

There are many different spaces and topics that this anchor activity is useful to ground our collective thinking about science and what it might mean to participate in science. Some of these come up in the moment where we can point to what we have said, written about, and reflected upon, and our initial thinking becomes a point of reflection. Others are planned with the intention to draw upon and potentially challenge our current conceptions of these ideas – or to interrogate whether school science experiences are aligned with the definitions they came up with. In what follows, I share some examples of conversations that occur at different points in our science methods course that both draw and expand upon this anchor activity. Please know this is not an exhaustive list, and I encourage instructors and students to continue to think about the spaces where this anchor activity can stimulate important conversations in their educational contexts.

How do these initial conceptions of science relate to your experiences in science classrooms?

When I began implementing this activity, this was not a conversation I thought we would need to spend too much time on. This was due to the belief that the pictures and stories would reveal their school science experiences, which we would work to interrogate. However, I have found over the years that students very rarely share pictures and stories of them participating in/with science in school. While the lack of photos from school science spaces might in part be due to pictures rarely being taken in school spaces, I still think it is significant that nearly all pictures of science that matter come from outside of school spaces. It also brings up the question of why we are so more likely to take pictures of us doing science that matters outside of school than inside. Regardless, the pictures they choose to share often connect to things they love to do (hiking, sports, cooking, outreach activities, robotics, etc.), the people they love to do these things with (e.g., grandparents, friends, family), and the places that matter to them (e.g., their community(s) and national parks). The conceptions of science participation are most often defined as active, collaborative, and engaged in better understanding a problem or phenomenon. Oftentimes, the pictures and stories involve something that they love doing, are passionate about, and consider fun. Their initial definitions become aspirational and something we use to think about in connection to their future classroom.

Due to their pictures and subsequent definitions emerging from informal spaces, I pose the question of how these conceptions compare to their school science experiences. This opens up space for us to think about two questions: how would you define your school science

experiences? And how does that definition compare to our conceptions from the anchor activity? There have been moments of alignment and congruence, but overall, we have found how they experienced school science was vastly different than the pictures and stories they shared with the class. While these preservice teachers generally enjoyed and/or were successful in their school science experiences, they often talk about learning as the pursuit of the right answer, understanding key vocabulary, and ensuring they do well on tests and quizzes. This is often contrasted by informal science experiences where they work to discover/uncover something about a phenomenon, connect science to their community, or simply have fun learning and participating in science. There are two things I want to note here. First, these are general trends over years of doing this activity and do not represent all student experience. Second, I do not ever position these two definitions as dichotomous (i.e., right or wrong/good or bad) but instead ask preservice teachers to consider the affordances, constraints, and feasibility of these definitions in classroom spaces.

Overall, these conversations result in definitions of science that uncover aspects of in-school and out-of-school science experiences that we can continue to reflect on and come back to. As we begin to spend time thinking about what we want learning and participating in science to look like in our future classrooms, these conceptions help us think about different elements of learning and experience that help frame those visions. These conversations have also helped students expand their notions of what science can be by considering more than what they experience in school spaces. We also use these definitions to think about the structures and potential barriers that result in science learning and participating. I have found over the years these are vital definitions and conversations for us to have in order to address the framing questions of the course.

How have others experienced science?

One of the most important conversations that builds off this anchor activity is focused on examining the ways in which others have defined and experienced science both inside and outside of school. As mentioned at the beginning of this paper, preservice teachers often draw upon their own experiences as students when thinking about what science in their classrooms can look like. However, as we know, the identities, cultures, communities, economic backgrounds, and past science experiences of preservice teachers do not always align with the students they will welcome into their classrooms (Milner, 2015). We also know that not all students experience science in the same way. Based on this, as a class, we explore the question: how might others define science participation and science that matters to them?

In order to do this, we dive into many resources with this framing question in mind. These resources include research studies that highlight and illuminate participation patterns in science across multiple identities (See Bang & Medin, 2010; Carlone et al., 2011; Birmingham et al., 2017), book chapters and essays written about science experiences (Roseberry & Warren, 2008; Tan et al., 2012), NSF (2021) documents detailing participation

rates in STEM majors and careers, student artifacts from my work with youth, and observations and reflections from preservice teachers' experiences with youth in formal and informal science learning environments.

The purpose of examining these resources is not to build a generalized definition of science and science participation for students who have different experiences than the preservice students in the course. Instead, it is to think through varied aspects of how different people experience science, as well as what that means for our future classrooms and the pedagogical strategies we employ in that space. These aspects include examining the barriers to participation in science that many experience based on their varied/multiple identities and discussing how science teachers can often reinforce these barriers through practices and/or environmental conditions (Bang et al., 2013). We investigate how past science experiences can impact the science-related identities students bring into the classroom ("I am not good at science" or "Science doesn't matter to me") and the strategies teachers can use to both recognize and help those students alter those identities. We examine conceptions of when, where, and how science matters to young people to think through the expertise and experiences that can matter for students when participating in science and whether there is space in science classes for those areas of expertise.

All of these conversations require us to look back at and critically examine our conceptions of science and participating in science from the anchor activity. Preservice teachers have opportunities to add to or edit their initial conceptions in a way that captures these changes and opens space to think about what this means for us as science teachers. Changes to their initial definitions are generally the case for preservice teachers at this stage, as their definitions come from the experiences of someone who was generally successful in science classrooms. I often tell these preservice teachers it took me longer than it should have to realize that I was not teaching thirty versions of myself when I was a new middle school teacher. These conversations provide opportunities for preservice teachers to think about their future students, what they might have experienced, and begin to think through actions they can take to provide opportunities for all students to participate fully. It also provides opportunities to recognize that their future students bring with them different histories, areas of expertise, experience, and wonder that matter to how they make sense of the world and their place in it. Finally, as their awareness and definitions begin to evolve, preservice teachers often pose the question – "what can we do?" This is a strategic spot to talk about pedagogical approaches and strategies for co-creating a classroom environment that opens space for a great number of students to feel a sense of belonging and success in science class. These conversations continue throughout the course as we engage in further investigation of teaching science in classrooms.

Learning from and about our students

As I began my career as a middle school science teacher, the idea of relationship building was one I was sure was important. However, the question remained: what aspects of getting to know students were important for their learning and participation in my science classroom? I knew I needed to go beyond the surface level to think about my students as both learners and people. With this in mind, an additional conversation this anchor activity opens up is to think about how we build relationships with our students and what is important to understand about them. I generally launch this conversation with the question: If you implemented this anchor activity in your future classroom, what might it tell you about your students? Below, I outline several ideas I push preservice teachers to think about (note that these are also things we can learn about preservice teachers as instructors).

Students' conceptions of science: The activity is set up in a way that requires students to make a decision in regard to what they will share. The decisions students make regarding which photo and story they present provide insights into how each student views/defines science learning/participation as well as insights into their varied experiences that shaped that definition. I share that middle school students in the past have shown me through their stories and pictures that science for them is participatory in ways that position them as active. They have shown me that science is used to understand phenomena in their everyday lives and can be directly connected to things they have observed and wondered about. Others have shown me that they see science as a collaborative and creative endeavor.

We talk about how this aspect of learning about students is vital to think about in connection to how we define science learning and participating in our own classrooms and builds off understandings from the previous area of examination above regarding how others experience science. We think about the ways in which these understandings about students can help us both get to know them as learners and plan science experiences that align with different aspects of their conceptions of science.

The potential relevance of science in students' everyday lives and cultures: The individual decisions students make also hold the potential to reveal aspects of their home life and culture and how those are bridged with science. Students might bring in pictures of themselves cooking with their grandmother, participating in faith-based ceremonies, participating in community events, working on a car with their families, and so on. These pictures reveal how these students see themselves participating in science in connection to who and where/what they care about. Rosebery & Warren (2008) argue that "whether the school likes it or not, students insist on bringing their everyday experience into the classroom and using it to think about scientific matters" (p.41).

In our methods class, we think about how this aspect of learning about their students can provide insight into the ways in which these everyday experiences can matter for participating in and learning science. Understanding and valuing what their future students bring from outside of school can help science teachers recognize and legitimize multiple

ways of knowing and doing science that can directly impact the participation of their students. Like most conversations opened up by this anchor activity, we continue to reflect back on this idea as we delve into designing lessons, assessments, and other aspects of their science classrooms.

Insight into students' interests, experiences, and areas of expertise: Finally, this anchor activity can provide insight into what students are interested in and what types of experiences they have had. In contrast to just knowing that a student likes sports, music, or video games (which is important), this activity provides insight into how these students see their interests in connection to science. I share with preservice teachers that students in the past have shared about trips they have taken, dance classes they are involved in, or their love of photography or music. All of these are shared in ways that connect to how science matters and can be a part of the things they are most passionate about. We use this idea as a class to reflect on the opportunities they might provide for students to bring in what they know and can do into their science classroom. I emphasize that this learning is especially salient when thinking about those areas of expertise that are not often legitimized in science.

Through these conversations, I have observed preservice teachers in discussions and reflections become more intentional about getting to know their students. This intentionality is connected to learning things about their students that might get them more interested or excited about being in science class, revealing why a student may harbor negative feelings for science that do not center on deficit thinking (i.e., “that student doesn’t care”), and helps preservice teachers better understand the importance of relationship building and its connection to science learning and participation.

Comparisons to Other Representations of Science

The final set of conversations we have as a class I want to make sure to highlight is in regard to other representations of science and science participation. For this aspect, we first examine readings about the Nature of Science and what that entails. We look across different aspects of the Nature of Science and whether our definitions of science/science participation from our anchor activities (both informal and formal) connect to those aspects (McComas, 1998; Feinstein, 2011). These conversations often lead us to think about the inclusion of creativity, subjectivity, and the social/cultural aspects of science knowledge production, what that means for what we have produced, and what that means for what we hope to bring to future science classrooms. These conversations often lead us to expand our notions of science or recognize different elements of our definitions that we had not yet highlighted in the course or experienced in a science classroom. These expansive notions generally include a conversation about which of these elements of the nature of science was prevalent in their school science experiences and which has been missing. Preservice teachers often talk about social/cultural aspects of knowledge construction as well as the

subjective nature of science as missing in many of their education experiences. This leads us to continue to think about authentic science learning and participating and what that can and does look like in classrooms.

From here, we start to examine common science resources that are used in classrooms, including science textbooks, classroom posters, and science activities that are commonly implemented. This investigation is framed around examining how science is defined in these resources as well as how science participation is represented. We then compare that with what we have created over time about these same ideas. This opens up conversations to both critically analyze these resources and further conceptualize what these preservice teachers hope that learning and participating in science will look like in their classroom. There are often large differences in what they want science to look like in their classrooms and how these resources depict learning and participating in science. We talk about how we might handle that and how making those differences explicit to students might help them expand their notions of science as well. As with the categories above, this conversation is returned to often as we examine different aspects of science teaching to reflect upon whether that particular strategy or activity aligns with and enhances the types of science learning experiences they hope to implement in their future classrooms.

Conclusion

In this paper, I have shared an anchor activity that I use to help preservice science teachers to first document and then build upon their conceptions of science and science participation. The activity and subsequent conversations open up space for preservice teachers to reflect upon different conceptions and experiences of science that their students will bring into their future classrooms. It also provides opportunities for our class to start breaking down the notion that our future classrooms will be places that reproduce climates, messages, and barriers that restrict science participation for many.

Of course, this is just one activity and set of conversations to begin this work. If we are committed to transforming science classrooms to be more inclusive and participatory spaces, what has been described here must be built upon throughout their time as preservice teachers and supported once they have entered the classroom. This is complex work, but work that is vital if we hope to ensure middle and high school science classrooms are dynamic and consequential for students of diverse identities, backgrounds, and interests.

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