PRE-SERVICE SCIENCE TEACHERS' ARTICULATION AND REVISION OF FRAMEWORKS OF SCIENCE TEACHING IN A JUSTICE-ORIENTED METHODS CLASS

By

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ABSTRACT

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The reasons particular people enjoy science, pursue science, and see themselves as science people, or not, are diverse and complex (Brickhouse, et al., 2000). The ways that teachers present science and value particular ways of knowing and doing in the classroom can influence which students see themselves as science people (Carlone et al, 2011). When teachers treat one particular cultural way of knowing in science as the superior way of knowing, specifically Eurocentric ethnoscience with its grounding in whiteness, heteropatriarchy, Protestantism, and settler colonialism, they create/maintain a hierarchy of knowledge that limits how all students can participate and see themselves in science, in particular girls, Black students, Indigenous students, and students of Color (Archer et al., 2010; Bang et al., 2012; Mutegi, 2013). Especially as Eurocentric ethnoscience is often presented as neutral, objective and universal (Harding, 2006), science teachers may not realize that there are multiple ways to know and do in science. In this study I draw from Gee's (2016) conception of Framework Discourse Analysis to posit that pre-service science teachers (PSTs) can be supported to articulate, question, and revise their socially-derived ideas/expectations of science and teaching (i.e., their "frameworks" of science and teaching) through participation in my two-semester long Science Teaching Methods Class focused on justice-oriented science teaching. Through a case study of three PSTs' select artifacts from the class and interviews the summer after the class, I identified each PST's frameworks of science and teaching, how PSTs questioned and revised these across Methods Class, and which types of Methods Class activities supported this articulation, questioning, and

revising of frameworks. I found that all PSTs clearly articulated their frameworks of science and teaching and that a pluralist/contextual framework of science was important in developing justice-oriented science teaching frameworks. In addition, the types of Methods Class activities that supported clearer articulation of science and teaching frameworks were those focused on connecting science and culture, expanding notions of what it meant to be a "successful" science student, and methods to recognize and address the sociopolitical in science and teaching in the classroom. These findings have implications for the use of Gee's (2016) Framework Discourse Analysis as a guide for raising critical consciousness and recognizing value in multiple ways of knowing and doing. In addition, they raise questions about criteria for recruiting pre-service science teachers and assessing their readiness to enter the field of teaching as justice-oriented science teachers.

This dissertation is dedicated to my grandma.
Thank you for teaching me to lovingly question.

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INTRODUCTION

There is a pernicious assumption, especially in school science, that science is "settled" (Bang et al., 2012), that what counts as scientific knowledge and practice has already been determined and has been determined to be the knowledge and practices generated by a set of white men. The science knowledge and practices of this restricted group of scientists is treated as objective and neutral, when it is, like all knowledge and practices, cultural, social, historical, and political (Harding, 2006). By treating this narrow set of knowledge and practices of white, male colonizers as objective, neutral, and the only knowledge and practices that count as science, this upholds systems of oppression such as white supremacy, heteropatriarchy, and settler colonialism. By determining that the science knowledge and practices generated within the social, cultural, historical, and political contexts of these white, male colonizers is the only science, the science knowledge and practices generated by people within any other contexts is automatically labeled as less than and outside of science. This has implications for who has access to and is seen to shape science, especially in schools where students are learning what science is and what it means to be a scientist. Students, especially girls, Black, Indigenous, and students of Color, must either change to conform to the narrow ways of being/knowing/doing sanctioned in this "settled" school science or be excluded from science (Archer et al., 2010; Mutegi, 2011; Bang et al., 2012). This assumption of "settled" science, when made explicit, underlies the problem with the notion of equitable science education as education which works to help all students accept and take up school science. When the curriculum only includes the science knowledge and practices generated in a narrow set of contexts, working to make students take up this "neutral" knowledge and practices is a form of cultural assimilation (Mutegi, 2011, 2013). This kind of cultural assimilation requires students to either reject the knowledge and

practices being presented to them and be labeled as failing or change important parts of themselves in order to take up knowledge and practice outside their own cultural contexts.

Multiple scholars have shown how the narrow, "settled" science of classrooms excludes students, especially girls, students that are Black, Indigenous, queer, or students of Color (Archer et al, 2010; Carlone & Johnson, 2007; Mutegi, 2011, 2013; Bang et al., 2012). Rather than trying to change these students to fit with a narrow set of science knowledge and practices, scholars have called for educators to "de-settle" science (Bang et al., 2012), make explicit the cultural and contextual nature of science (Harding, 2006), and expand what counts as science and success in school science (Carlone et al., 2011) to more accurately support a plurality of ontologies and epistemologies in science and science education. This would help science education be not only accessible to students, but is relevant to, shaped by, and useful to students and communities (Morales-Doyle, 2015; Birmingham et al., 2017). This is why some scholars have conceptualized equity as going beyond access and inclusion (Philip & Azevedo, 2017; Calabrese Barton & Tan, 2019, 2020) and requiring explicit attention be paid to context (Morales-Doyle, 2020). These scholars align with Medin and Bang (2014) who press for science to be treated as the cultural, contextual knowledge and practices that it is and for what counts as scientific knowledge and practices to be expanded to include knowledge and practices that go beyond what Medin and Bang (2014) call "Eurocentric ethnoscience".

To create science education that actively and explicitly draws from multiple contexts and cultures in science, focuses on connecting students with the science knowledge and practices they already utilize, and expanding their knowledge and practices in ways that matter to students and communities, science teachers must be prepared to de-settle science for themselves and recognize the ways cultural, social, political, and historical contexts shape and are shaped by

science. Part of this process involves teachers recognizing their own particular contexts and those of the knowledge and practices with which they are familiar so as to recognize that all knowledge and practices are contextual. This will help expose as false the myth that Eurocentric ethnoscience is objective and neutral.

Teacher educators have been studying ways to prepare novice teachers to work with diverse students and the multicultural/contextual knowledge and practices they bring to school and science. Many scholars who have focused on how to prepare novice teachers to teach in equitable or justice-oriented ways have highlighted the importance of PSTs raising their critical consciousness, especially in relation to the ways whiteness has and continues to shape schooling (Carter Andrews et al., 2019; Matias, 2013) and science education (Mensah & Jackson, 2018). Teacher educators have worked to support PSTs in raising their critical consciousness and understanding the role whiteness plays in schools and science through the use of multiple strategies and tools. Matias (2013) described how she used exposure to and discussion of texts that share the emotions connected to racism and the historical, political, cultural, and social creation of whiteness to help her white PSTs understand their own whiteness and the ways racism impacts people of Color both in and out of schools. Carter Andrews et al. (2019) brought in multimodal texts and methods of expression that represented multicultural ways of being and knowing to support PSTs in questioning and resisting binaries that oversimplified and made invisible and normal oppressive social structures and ideologies. Mensah and Jackson (2018) helped their PSTs experience science (lessons) that were relevant to students' interests and goals to push back on and expand the narrow conception of who and what science was for. Both Carter Andrews et al. (2019) and Mensah and Jackson (2018) highlighted the utility of PSTs creating a critical autobiography related to schooling and/or their specific discipline. Calabrese Barton

(2000) guided her PSTs through service learning with youths experiencing homelessness in ways that highlighted the valuable knowledge and perspectives these youths brought to science. These strategies and tools supported PSTs in questioning the ways of being/knowing/doing that have been normalized in school and science and approaching multiple ways of being/knowing/doing with an assets-based lens.

These scholars primarily focused on ways to shift the ways PSTs thought about teaching, science, and/or their students and their relationships to systems of power. The balance between focusing on theory/ways of thinking and practices has been the subject of research and debate in teacher preparation. For example, Ball and Forzani (2009) proposed focusing teaching preparation around certain core teaching practices as providing PSTs with concrete things they can do in the classroom can be helpful in their developing teaching practice. Philip et al. (2019) responded with an important concern that by prioritizing particular "core" practices, issues of equity would be pushed to the side. Calabrese Barton et al. (2019) posited that the binary between core practices and equity was unnecessary and that these teaching practices (i.e., high leverage practices) themselves could be focused on equity. When preparing PSTs to teach science in justice-oriented ways, it is clear that both theory/stance and practice must be considered in tandem. PSTs can be provided with examples of teaching practices and opportunities to try them out, but developing a clear framework of teaching is essential for PSTs to take these practices and adapt them in the innovative ways necessary to apply them effectively in their new classroom context (Thompson et al., 2013). In teacher preparation, we can include multiple tools and strategies to support PSTs in raising their critical consciousness, as several scholars have determined (Matias, 2013; Carter Andrews et al., 2019; Mensah & Jackson, 2018). This critical consciousness raising alone is not sufficient. PSTs need to be able to integrate what

they have learned about systems of power and multiple ways of being/knowing/doing into their conceptions of what it means to teach and what it means to do science. This is where I turn to Gee's (2016) conception of "frameworks" as a way to think about PSTs to explore multiple ways to be/know/do in school and science and to connect this to the way they think about what it means to teach science and how this shapes their teaching practice.

The ways that people act in and interpret the world are guided by their frameworks, which are derived from their experiences in the world and the norms and expectations of their communities. Gee (2016) described frameworks as sets of claims about how a particular thing will occur or respond, how these things are related and interact, and "certain ways of valuing, assessing, and appreciating these things and their relationships," (p. 349). For example, a person might draw from a framework of science as a set of absolute truths about the world. Based on this framework, this person might expect scientific knowledge to be concrete and infallible information to be memorized and taken as fact without question. Based on this framework of science as absolute truth, this person might hear that a particular product or idea is backed by science and trust the statement about this product or idea implicitly. This framework can exist alongside other frameworks, such as a framework of science as a process of discovery. While this framework might seem to conflict with the framework of science as absolute truth, a person might draw from each framework in a different context or perhaps they might resolve this apparent conflict by including a claim that these absolute truths are discovered by an elite group of people called scientists.

These frameworks, like all frameworks, are socially derived. These personal frameworks are tied to broader ideologies of the societies and communities to which people belong/in which people live. By ideologies, I am referring to broad ideas of how the world works that are

typically normalized, treated as neutral and implicit (Benford & Snow, 2011). While ideologies are broad, implicit, normalized ideas about the world, frameworks are personal, individual ideas of how the world works, what to expect, and how to interact in the world. These personal frameworks are connected to ideologies in that accepted ideologies shape individuals' experiences in the world and how they come to expect things to behave and interact. In turn, individuals' personal frameworks influence how they act in and interpret the world, which can also shape ideologies.

Typically, ideologies and personal frameworks are left implicit and their influence on people's actions is unconscious. When people's personal frameworks align with dominant ideologies, it is unlikely that there will be conflict or incentive to critically analyze or consciously shape their personal frameworks. It can be difficult to recognize that leaving frameworks of science implicit is harmful, especially if one's own framework aligns with the ideology that has been normalized. This is complicated by a widespread ideology of science as neutral and objective paired with teaching a particular framework of science as neutral and objective. If one accepts that their framework of science is neutral and objective, one is unlikely to notice the social, historical, and political influences on this science, especially if these are the social, historical, and political contexts one has grown up in. Without recognizing the social, historical, and political nature of science, it is difficult to critique, change, and make conscious decisions about the kind of science to support and pursue. When teachers' frameworks of science go unacknowledged and unexamined, they are likely to treat their particular framework of science as neutral and objective rather than what it is, which is a particular way of making sense of the world based in the social, historical, and political contexts of the teacher's life and education, as well as the contexts of the people whose science knowledge and practices the

teacher has been exposed to. For U.S. science teachers, the frameworks of science that they are likely to have been exposed to are White, masculine, heterosexual, settler colonial frameworks (Mutegi, 2013). When this science based in White, masculine, heterosexual ways of knowing and being is treated as neutral and taught as though it is science for everyone, this is a hidden form of cultural transmission (Mutegi, 2011). By treating this one form of science as neutral, this sets this one form of science as the norm and by definition treats all other forms of science as other or less than. Students and teachers who share these White, masculine, heterosexual ways of thinking about and acting in the world will likely have little trouble accepting this form of science as it aligns with their framework for understanding the world. However, this treatment of one framework of science as the only framework of science is damaging for the students who share this framework and the students who bring different frameworks to science and the classroom. Students with different frameworks for interpreting the world will feel the misalignment and be less likely to engage in science (Archer et al., 2013; Medin & Bang, 2014) and all students, including those whose frameworks align, will be exposed to science that provides a superficial understanding of how this science knowledge/practice was developed and how it might and should be adapted and applied in particular contexts to support knowledge generation and informed decision-making.

People do not have to maintain the same personal frameworks forever, but they do have to be aware of their frameworks and the claims and assumptions underlying them in order to question these assumptions and adjust these claims. According to Gee (2016), people can adjust their frameworks by adopting an "interpreters framework" in which they: acknowledge their own frameworks and its underlying claims and assumptions, are open to engaging with the frameworks of others, and use their experiences with these other frameworks to make

adjustments to the claims and assumptions that no longer align with their interpretations of experiences in the world. It is this process that can support people in making conscious decisions about their actions and the frameworks that guide them, which can in turn, reshape ideologies. Rather than unconsciously acting in ways that are guided by implicit frameworks shaped by unnamed ideologies, people can make their own frameworks and the ideologies underlying them explicit and consciously decide which claims and assumptions they choose to use to guide their actions and interpretations of the world. In this way, people will be consciously aware of why they are acting in particular ways rather than simply acting in ways that have been normalized.

As an example of the importance of making explicit the underlying claims and assumptions for how we act in and interpret the world, I am reminded of a story from martial arts. A student was taught to wrap their belt three times around their waist before knotting it. When the student went to another school, they learned that everyone at this school wrapped their belt only twice before knotting it. The student asked their original teacher why they wrapped their belt three times before knotting it. The teacher replied that this was how their teacher taught them to tie their belt. The student went to their teacher's teacher and asked the same question and was given the same answer. The student went from teacher to teacher until they found the original teacher of the school, a tiny man living on top of a mountain. When the student asked this man, "Teacher, why do we wrap our belt three times before knotting it?" The teacher replied, "Look at me! My waist is so narrow, if I only wrapped my belt twice, the ends would be too long." This story illustrates that understanding the context and reason behind our actions can help us better make decisions about those actions and how to adapt them to our current context.

The conscious understanding and examination of frameworks and their related ideologies is especially important for teachers. The ways teachers represent their discipline and the practices

they treat as normal can serve to include and exclude students depending on students' frameworks of school in general and the discipline more specifically (Bang et al., 2012; Mensah & Jackson, 2018). The ways teachers present their discipline can also perpetuate normalization of particular frameworks or support conscious analysis of those frameworks and the ideologies tied to them. Because we tend to leave ideologies and frameworks implicit, especially when these align with dominant ideologies tied to Whiteness, heteropatriarchy, and Christianity, it is especially important to work with teachers to make explicit their own frameworks tied to teaching and their discipline (Berlin & Berry, 2018; Le & Matias, 2019), explore how those frameworks developed and the ideologies they are tied to, engage with different possible frameworks and ideologies, and use this to make intentional choices about the frameworks of teaching and their discipline which they want to bring to their classrooms.

In thinking about science education, I considered two main questions: "What is science?" and "How is this science taught?" When thinking about what science is, I drew from two ways of thinking about science, especially in schools: that of "science" as universal and that of science as pluralistic. In the first characterization of science, I put science in quotes to denote that the science referred to is science from a particular set of people in particular social and cultural contexts, this is what Medin & Bang (2014) have referred to as Eurocentric ethnoscience. In this universalist view of science, science knowledge generated by primarily western European, white, cishetero, Protestant, colonist, white men is treated as truths that can be universally applied to explain the world (Mensah & Jackson, 2018). By assuming that science from this particular group of people is neutral and can be applied universally, this particular scientific knowledge is treated as neutral and labeled simply as "science" rather than a more descriptive "European ethnoscience". By treating this science as universal and neutral, the relationship between the

humans who created this science and the science itself is hidden. The cultural, social, historical, and political contexts of the generation of this scientific knowledge are made invisible. By treating science generated by this particular group of people with their particular social, cultural, historical, and political contexts as neutral and universal, this sets up a binary of European ethnoscience as "science" and everything else as "not science". By default, any science that is labeled to indicate its cultural, social, historical, political, or geographical context is seen as not true science, but cultural knowledge, which is seen as interesting, but not truth about the world. This science knowledge is treated as not science and as a lesser form of knowledge. By making the cultural nature of the knowledge explicit, those who ascribe to a universalist view of science would judge this knowledge to be not neutral, not objective, not science (Bang et al., 2012; Harding, 2006). This binary excludes science done outside western Europe, by Black, Indigenous, and people of Color, by females, queer folks, and people of religions other than Protestantism. Because the scientific knowledge generated by western European, white, cishetero, protestant, settler colonist men is treated as universal truths about the world, when science is taught, it is taught as a set of truths to be communicated to students. This lends itself to teaching as telling and when people talk about "science for all", they mean that teachers should help students who do not already see the world from a Western European, white, cishetero, protestant, male point of view should be helped to take up that view, regardless of how that view conflicts with their identities, experiences, and values because in this view/framework, the science is immutable truth, so the children must be the ones to change.

In contrast, people can think of science from a pluralist perspective in which there are multiple ways to think about and construct knowledge about the world. These ways of knowing and doing are tied to people's cultural, social, historical, and political contexts and the

connections between these contexts and the ways that science is done and the knowledge generated should be made explicit and used to more deeply understand the scientific knowledge and methods themselves. This pluralist view of science makes the relationship between humans and science explicit and a subject of inquiry. Science is treated as dynamic, uncertain, always in process and being worked on and questioned by multiple people from multiple contexts with multiple perspectives to bring to bear to the questions and problems under investigation. In a pluralist view of science, multiple ways of knowing and doing are integrated in the exploration, questioning, explaining, and acting in the world. When science is seen as pluralistic, there is not binary of what is or is not science that excludes the majority of people based on their culture and identities. Instead, multiple ways of exploring and explaining the world are discussed and contribute to deeper understanding of the world through consideration of multiple ways to question, generate and interpret evidence, and create explanations of phenomena. To teach this kind of science, teaching would focus more on facilitating inquiry, discussion, questioning, and co-creation of meaning and knowledge drawing from multiple ways of knowing and doing. "Science for all" means co-creating knowledge of the world by drawing from lived experiences, cultural and social ways of knowing and doing, and pursuing goals set for the self and communities. This is a vision of "science for all" described by Calabrese Barton (1998) and Mutegi (2011) as they explained the importance of bringing together science from multiple cultural contexts into school science.

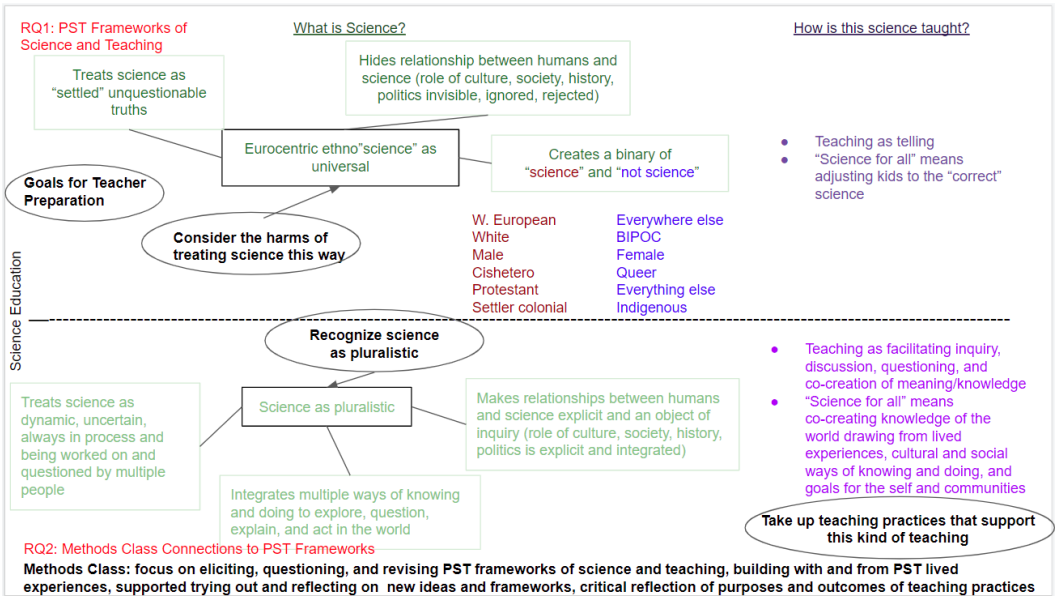
There have been multiple calls to prepare science teachers to teach in ways that support the participation of diverse students without expecting those students to ignore or change parts of who they are to take up science in school. To support preservice science teachers in teaching in these ways that include and value diverse students for who they are and what they bring to

science and the classroom and disrupt norms and practices that exclude and marginalize these students and the knowledge of particular groups (e.g., BIPOC, girls, queer folks), teacher educators should support PSTs in recognizing science as pluralistic, considering the harms done by treating Eurocentric ethnoscience as universal, and must work to support PSTs in taking up teaching practices that support teaching science in a way that values student ideas and lived experiences and creates opportunities for students to question and investigate and generate knowledge in ways that are meaningful to them and support acting in and transforming their communities. This is justice-oriented teaching and it requires taking up a notion of rightful presence of students of all backgrounds in science classrooms and explicitly discussing, questioning, and drawing from science knowledge and practices from multiple social and cultural contexts.

The focus of this study was a Methods Class in which I and my co-instructor(s) designed the pedagogy, structure, and activities of the course to support PSTs in recognizing science as pluralistic, considering the harms of maintaining a framework of Eurocentric ethnoscience as universal, and taking up teaching practices that would support explicit student engagement with science from multiple cultural, social, and political contexts. One of the ways we (instructors) did this was by operationalizing Gee's (2016) Frameworks Discourse Analysis to support PSTs in analyzing their own and others' frameworks toward deeper understanding of those frameworks. We designed learning opportunities centered on supporting PSTs in first articulating their own frameworks of science and teaching and what experiences, assumptions, and values supported those frameworks. It is essential to know what your own ideas are and what supports them to be able to critically discuss them. Next, we designed learning opportunities in which PSTs experienced, read, heard about, or watched examples of science and teaching shaped by a

variety of frameworks. Engagement with these varied frameworks was scaffolded to support open minded discussion and questioning of these frameworks and their relation to each class members' frameworks. Finally, we designed opportunities throughout Methods Class for PSTs to reflect on their own and others' frameworks and revise their frameworks based on new experiences and ideas. The first research question of the study focused on participant PSTs' frameworks of science and teaching and how those were articulated, questioned, and revised across Methods Course, with particular attention paid to elements/claims of frameworks related to science as universal or pluralistic and teaching as adjusting students to science or of co-creating meaning with students who are welcomed as exactly who they are. The second research question focused on Methods Class itself and the particular activities that supported PSTs in articulating, questioning, and revising their frameworks of science and teaching in the ways that they did. The relationships between considerations of what science and teaching are and how this connected to PST frameworks and the research questions of this study can also be seen in Figure 1 below.

Figure 1. An Overview of the Study



Research Questions

1. What are pre-service science teachers' (PSTs') frameworks of science and teaching and how do PSTs articulate their frameworks of science and teaching across Methods Class?
2. How did learning opportunities in Methods Class support PSTs in articulating and developing their frameworks of science and teaching?

THEORETICAL FRAMEWORK

In this study, I focus on the frameworks related to science and science teaching that guide teachers' planning, implementation, and reflection on their teaching. I draw on Gee's (2016) work extensively to define frameworks and outline the importance of having critical discussions about/across different frameworks, even when these frameworks are conflicting. Gee (2016) defines frameworks as "...sets of ideas that guide us in what to expect and how to value, assess, or appreciate things and happenings in specific situations," (p. 351). Everyone has multiple frameworks based on the cultures and communities they have been socialized into and these frameworks shape and are shaped by the ways people interact with and interpret the world. Frameworks guide what we count as science, how we do science, and how we think about teaching science. These frameworks help us decide who can do science, which questions, methods, and evidence count as scientific, as well as what it means to teach science. Teachers, both pre-service and in-service, make decisions about how to teach based on our expectations of what a teacher should do, how a teacher should interact with students, what a teacher should know, what a student should know, how a teacher should represent themself (to name a few). Often, these frameworks of science and teaching are left implicit and uncontested or unexplored.

Frameworks are socially-derived. People learn "what to expect and how to value, assess, or appreciate things or happenings in specific situations" (Gee, 2016, p. 351) through their interactions in their communities. People learn what it means to teach by watching their teachers as students, by exposure to depictions of teachers in the media (e.g., books, movies, TV shows, news reports), by hearing people around them talk about teachers and teaching. All of this happens before teachers start their official professional preparation in teacher preparation programs. Then, through these teacher preparation programs, an additional layer of what it

means to teach is added through classes taken, peer teaching, interactions with mentor teachers and the students of mentor teachers. All of these sources help teachers create their framework of what it means to teach. All of these sources are also situated in a society made up of multiple frameworks both directly and indirectly related to teaching. For example, in a society that expects there to be two genders, we see teacher talk moves that suggest addressing the class as "boys and girls." We see schools with boys and girls bathrooms. We see strategies of asking students to line up in a boys line and a girls line or dividing teams up into a boys team and a girls team. All of these activities are both created by the social framework of two genders and reinforce this framework of two genders. This framework of two genders is not an explicit framework that is taught in teacher preparation, but it does influence frameworks of teaching. The same is true of all other social frameworks. These frameworks are not isolated from one another.

Frameworks interact and influence one another. As most teachers in the U.S. have derived their expectations of what it means to do science and to teach through their participation in communities situated in a society with white supremacist, heteronormative, patriarchal norms and values, these frameworks of science and teaching and learning are likely grounded in White, masculine, heteronormative ideas (Bang et al., 2012; Gee, 2016). These ideas become especially problematic when they are left unrecognized and treated as the only valid way of observing, forming expectations of, and making decisions about the world and our actions in it. This idea that our own framework(s) is/are the only valid framework(s) is reinforced when two conditions are met. The first is that we may not consciously recognize our own framework(s), which makes it difficult to understand any framework other than our own so we end up confused or convinced that the other framework is wrong, misinformed, misguided, or ignorant. The second difficulty is

that even if we do recognize that there are two or more different frameworks involved, we may think that our goal in interacting with the unfamiliar framework, and the person guided by this framework, is to convince that person that their framework is wrong (Gee, 2016). It is difficult to interact with unfamiliar frameworks without recognizing our own familiar framework and when our goal is to convince others that our own framework is the only correct framework. This becomes especially problematic as a teacher when the teacher's own framework conflicts with the curriculum's guiding framework and when students bring frameworks with which the teacher is unfamiliar. If the teacher does not recognize their own framework or the framework of a student, for example, the teacher may think that the student's ideas are simply misguided and the teacher will then attempt to help the student see why they are incorrect. Rather than helping the student correct misinformation, the teacher would be attempting to invalidate a way of interacting with the world that the student has derived from their communities. This has been referred to as epistemic injustice or epistemicide (Fricker, 2007) where a person's way of knowing is invalidated and oppressed.

While dealing with different and unfamiliar frameworks can be difficult, Gee (2016) argues that if people have an open mind and goodwill, engaging in critical discussions of conflicting frameworks can help us deepen our frameworks and even adjust our frameworks as we find common ground between these conflicting frameworks. (While Gee (2016) focuses on conflicting frameworks, I believe the same process will work for critical discussion of any two frameworks.) The way to do this is to focus on explaining and understanding the two frameworks rather than seeking to convert or convince the other person that one framework is the correct framework. Gee (2016) draws on a hypothesis from philosophy of science (the Quine-Duhem hypothesis) as a starting place to discuss how to better understand and shift frameworks.

According to this hypothesis, theories, or frameworks, are composed of sets of claims supported by evidence. When we discuss ways of interpreting the world, it does not make sense to address an individual claim, but rather to compare/discuss entire frameworks/theories. As Gee (2016) points out, when an experience or evidence contradicts a theory, the scientist has choices about which associated claims to reject or adjust and the scientist can make these decisions based on which assumptions underlying each claim no longer seem useful. Everyone can go through a similar process with their own theories, or frameworks, of how the world works as long as they have an open mind and are willing to discuss conflicting frameworks with the goal of better understanding these frameworks and the evidence and assumptions underlying them. The teacher who has a heteronormative framework that interacts with their science framework can, through critical discussion of their own familiar framework and an unfamiliar framework (such as a framework informed by queerness as normative and binaries upheld by heterosexuality as the baseline for relationships as unhelpful) gain a deeper understanding of both frameworks, their affordances and constraints, and perhaps adjust their claims and assumptions about what counts as science and the ways heteronormative and queer views of the world support different interpretations and explanations.

We see examples of the heteronormative framework in science in the field of animal behavior in which field scientists observed sexual behaviors that did not conform to male-female pairing for reproductive purposes, but worked to fit these animal behaviors into this male-female reproductive pairing framework based in heteronormativity (Monk et al., 2019). Teaching animal behavior this way in science class reinforces this idea of heteronormativity, which is not only bad (or at least extremely limited) science, but also reinforces this framework for students who are internalizing the idea that only male-female reproductive pairings are normal, any other sort of

pairing up or sexual relationship is abnormal. This can be detrimental for all students, those whose own views of the world are being limited and those whose ways of being in the world are being labeled as abnormal. Teachers need to have critical discussions about these frameworks so they can recognize, become familiar with, and see the affordances and constraints of multiple frameworks in order to shift science education that produces more robust science knowledge and practices (not limited by limited frameworks) and to support their students in recognizing, valuing, and critically analyzing multiple frameworks for themselves.

In order to have these critical discussions toward deeper understanding of frameworks, Gee (2016) suggests that we need an "interpreters framework" (p. 357) in which we recognize that we do not have truth, but rather, we are always interpreting our experiences, observations, and interactions in the world. It is through thinking critically about the ways we interpret the world based on which values, assumptions, and experiences, and considering these in light of how another framework guides interpretation of the world based on that set of values, assumptions, and experiences that we can better understand our own frameworks and adjust them through adjusting the claims they are based on as we find common ground between different/multiple frameworks.

In order to better understand our frameworks as teachers and perhaps adjust these so they do not unconsciously support white supremacist, heteropatriarchal versions of science in the classroom, we need opportunities and tools to critically discuss our own frameworks and unfamiliar or seemingly conflicting frameworks (e.g., feminist, anti-racist, queer). Beyond this, teachers also need support in learning how to teach in ways that help their students have critical discussions about conflicting frameworks because it is through deepening our understanding of and adjusting our frameworks to find common ground among multiple frameworks that we get

closer to truth (Gee, 2016) and in doing so, we become more fully human and create richer science knowledge and practices.

As pre-service teachers recognize, critically discuss, and adjust and expand their frameworks of science and teaching, they become part of a vision of science education that supports people with multiple frameworks (and therefore, multiple cultures and identities) in participating in and creating science through recognition and understanding of the strengths that each framework brings to different contexts. Therefore, when I look for pre-service teacher learning in this study, I look for pre-service teacher recognition of their own (familiar) frameworks, recognition of unfamiliar frameworks, critical discussion of the affordances and constraints of each framework in particular contexts, and consciously drawing from multiple frameworks to make sense of and explain a phenomenon.

Importance of Recognition and Inclusion of Multiple Ways of Being, Knowing, and Doing

Preparing teachers to work with diverse students has been, and continues to be, an important concern for teacher educators. Several scholars have explained the problems that arise when teachers and students do not share social, cultural, racial, ethnic, and/or class backgrounds (Dixson, 2003; Kohli, 2009). Often, the focus is on the disconnect between white, middle-class teachers' and diverse students' experiences and expectations in the world (Sleeter, 2001). Some scholars have focused on the benefits of recruiting a more diverse body of teachers or putting students and teachers with similar backgrounds together in the classroom (Dixson, 2003). Other scholars have focused on the need to prepare white, middle-class female teacher candidates to understand, value, and work with students who are BIPOC and from families of varied socioeconomic status (Sleeter, 2001). Both of these approaches support the creation of a classroom environment in which students are valued and welcomed for who they are. Both

approaches require teachers to recognize and value multiple ways of being, knowing, and doing in the world and in the classroom. Because schooling is grounded in white, masculine, middle-class, heteronormative ways of being, knowing, and doing, to be a BIPOC, female, low-income, and or queer person in the classroom is to have to navigate more than one way of being, knowing, and doing. In the case of teachers and students who fit into the ways of being, knowing, and doing that are typically privileged in schools, they must be supported in recognizing this as a particular way of being, knowing, and doing and to welcome diverse ways of being, knowing, and doing. Recognizing and actively including multiple ways of being, knowing, and doing is an important part of creating a classroom environment that supports all students to learn and thrive and grow. As schools have not been created/designed to support, include, and value multiple ways of being, knowing, and doing, teachers must be prepared to teach in ways that counteract the normalization of one particular way of being, knowing, and doing. For example, Baker-Bell (2020) focuses on linguistic justice, in particular for students/communities who use African American Vernacular English, or Black language, which has roots in Bantu African languages as well as British English as adapted by enslaved persons brought to North America by colonists. Typically, in schools, the language treated as "correct" or "standard" is English that comes from British English roots of colonists. These are two language systems used to express ideas which have developed in the United States under particular historical contexts. Both are valid language systems and treating one as the "correct" English and the other as incorrect, slang, or inferior, as is often done in schools, is a form of linguistic injustice. This is an example of two linguistic frameworks that students bring to school. Recognizing both of these frameworks, understanding their historical, social, and cultural

contexts, and actively welcoming and working with both in classrooms would be an example of justice-oriented teaching.

Difficulty Recognizing Normalized Ways of Being/Knowing/Doing

It can be difficult to recognize a particular way of being, knowing, or doing as one of many ways of being, knowing, or doing when that particular way is treated as the norm. This is similar to when a person travels to another country and notices "the culture" of that new place. (Clearly, people do not need to travel to another country to experience a difference in culture, but often cultural differences are more likely to be noticed and expected when traveling internationally.) The traveler may simply notice the differences in how people are, know, and do and think they are strange or incorrect or interesting without questioning why their own ways of being, knowing, doing seem normal to them. The traveler may instead start to recognize their own ways of being, knowing, doing as tied to social and cultural contexts. Sometimes, exposure to different ways of being/knowing/doing can help people notice their own normalized ways of being/knowing/doing and with appropriate scaffolding, people can question why these different ways of being/knowing/doing have developed and been normalized in different contexts. Providing prospective teachers with exposure to multiple ways of being/knowing/doing in schools can help those prospective teachers recognize that the ways of being/knowing/doing that have been normalized are not necessarily the best ways to be/know/do in schools, but simply the ones that have been made the norm. Recognizing that there are multiple ways to be/know/do in schools is a first step. Supporting teachers to question both what the affordances and constraints of these ways of being/knowing/doing might be, as well as the purposes behind supporting or impeding different ways of being/knowing/doing is a helpful next step for prospective and practicing teachers as they consider how to support students.

Supporting Critical Engagement with Multiple Ways of Being/Knowing/Doing

If we, as teacher educators, want to prepare teachers to work with diverse students and support their students to work constructively with diverse people (by "diverse" I mean people with varied social and cultural backgrounds, this can include, but is not limited to diversity in race/ethnicity, gender, sexual orientation, income), we need to support teachers in understanding, recognizing, valuing, and actively including multiple ways of being/knowing/doing in the classroom. One way to do this is to expose teachers to multiple ways of being/knowing/doing and discussing the experiences, values, and assumptions behind these and then connect this back to teachers' own ways of being/knowing/doing and how these are connected to experiences, values, and assumptions tied to social/cultural contexts.

Gee's (2016) FDA and Preparing Justice-oriented Teachers

Gee (2016) sought to address exactly this issue of how to support people to engage productively with people with different or seemingly conflicting viewpoints. Gee (2016) called these different viewpoints or ways of interpreting and acting in the world, "frameworks" and explained how frameworks are socially derived sets of claims. He also explained the importance of seeking to better understand our own and others' frameworks through interaction rather than seeking to prove someone else's framework wrong by attacking a particular claim in their framework. This focus on deepening understanding of our own and others' frameworks seemed like a useful way to support teachers in engaging with students and their diverse frameworks.

The main ideas that I take from Gee's (2016) FDA are that the ways people interpret and act in the world are tied to social/cultural contexts and that it is through interacting with people with different frameworks with the goal of deepening understanding of our own and others' frameworks that we can support people, in this case teachers and students, in constructively

interacting with each other while deepening our understanding of the world. This kind of interaction with the goal of deepening understanding requires and supports recognition and valuing of our own and others' frameworks (which shape and are shaped by our ways of being/knowing/doing). Gee (2016) explained that the ways people articulate their understandings of the world are tied to social/cultural contexts and make visible these contexts and their derived frameworks. Through articulation and examination of frameworks, people/teachers can deepen their understanding of their own frameworks and those of others. This sort of examination of multiple frameworks both supports and is supported by critical consciousness raising and enactment of multiple ontologies and epistemologies in the classroom.

Operationalizing Gee's (2016) FDA in Methods Class

I see Gee's (2016) notion of critically discussing our own and others' frameworks towards deepening understanding of multiple frameworks as a useful way to support pre-service science teachers (PSTs) in developing justice-oriented science teaching practices. As elaborated in the Literature Review, justice-oriented science teaching involves welcoming students for who they are through an assumption of their rightful presence in school and science (Calabrese Barton & Tan, 2019, 2020), actively including multiple ways of being/knowing/doing in the classroom (Bang et al., 2012), and supporting students in understanding and intentionally shaping the world in ways that matter to them (Freire, 1970; Birmingham et al., 2017). Through deepening understanding of their own and others' frameworks of science and teaching, PSTs might recognize that they have frameworks, that their frameworks of science and teaching are not the only valid frameworks, and that students bring valuable ideas and experiences to science and school.

To operationalize Gee's (2016) notion of Frameworks Discourse Analysis, of "testing and reflecting on whole frameworks (all the claims in them as inter-related claims) in the face of different ways of talking about and looking at experience," (p. 352), with PSTs, we (instructors) designed opportunities in Methods Class for PSTs to articulate their own frameworks of science and teaching, to critically discuss and question their own and others' frameworks, and to revise their own frameworks based on new information, experiences, and ideas. We (instructors) designed opportunities for PSTs to engage in all three of these steps iteratively across the two semesters of Methods Class.

Three Steps for Deepening Understanding of Own and Others' Frameworks

Critically engaging with multiple frameworks of science and teaching is meant to support PSTs' critical consciousness raising, development of an asset-based lens of students and communities, and their design, implementation, and reflection of science lessons, units, and classroom environments that honor students' rightful presence in school and science, welcomes and actively includes multiple ways of being/knowing/doing in school and science. This critical engagement with frameworks of science and teaching involved three main steps: (1) articulation of frameworks, (2) critical discussion of frameworks, and (3) reflection and revision of frameworks. There is overlap across the Methods Class activities in the three steps.

Articulate Frameworks

PSTs expressed what science and teaching were to them, including what science and teaching looked like, what they involved, and which experiences, ideas, values, and assumptions shape and have shaped these ideas of science and teaching. In Methods Class, PSTs primarily articulated their frameworks through their Science Story editions and Weekly Reflection Journal.

Critically Discuss Frameworks

PSTs considered ways of being/knowing/doing in science and teaching and what experiences, values, assumptions shape and have shaped these ways of being/knowing/doing. PSTs asked themselves and others why they thought what they did about science and teaching. PSTs considered affordances and constraints of their own and others' frameworks (ways of being/knowing/doing) of science and teaching in particular contexts. In Methods Class, PSTs primarily critically discussed frameworks during class activities and discussions in which PSTs were presented with opportunities to share their own experiences and frameworks and with opportunities to consider and discuss varied frameworks in the form of written, spoken, or video recorded scenarios in science and/or classrooms. PSTs were presented with question prompts and/or activities to scaffold their examination and critical questioning of the focal frameworks underlying the content presented in class. For example, we (instructors) provided PSTs with several written scenarios of teachers and students with different frameworks of science and/or school, the interactions between these teachers and students, and the outcomes depending on how and whether teachers recognized and included multiple frameworks in the interaction.

Reflect on and Revise Frameworks

PSTs considered how experiences, ideas, and values of others' frameworks were related to and could inform their own frameworks. PSTs reinforced, adjusted, and/or rejected claims in their frameworks based on their reflection on these experiences, ideas, assumptions, and values. In Methods Class, PSTs reflected on multiple frameworks and revised their own frameworks through the multiple editions of their Science Story and their Weekly Reflection Journal entries.

Limitations of Gee's (2016) FDA

As with any framework, there are several limitations to using Gee's (2016) Frameworks

Discourse Analysis (FDA), especially to support PSTs in becoming justice-oriented science teachers. In this section I discuss the implications of Gee's (2016) limited attendance to cultural context and implications of too much or too little "tolerance" in frameworks.

Cultural Context of FDA

Gee's (2016) goal with his Frameworks Discourse Analysis (FDA) was to posit discourse analysis that was useful across cultures and differing viewpoints. Gee (2016) acknowledged that he was writing about frameworks and discourse analysis from what he referred to as a Western, US perspective and that these ideas might be taken up differently by people with different cultural perspectives. He did not discuss possible cultural differences or ways that frameworks and discourse analysis might be constructed or utilized differently. Instead, Gee (2016) laid out his ideas of the ways people use words to "cut up" the world and how these ways are shaped by culture and shape ontologies. In this way, Gee (2016) acknowledged the relationship between culture, discourse, and frameworks and the importance of understanding the ways cultures, discourses, and ontologies shape each other. He did not discuss the ways his own culture shaped his discourses and ontologies, in particular the ways he thought and wrote about frameworks. Gee (2016) wrote that frameworks were socially and culturally contextualized, which is an idea I draw on in this study, but Gee (2016) did not address the idea that his very way of conceptualizing frameworks was socially and culturally contextualized, not neutral and necessarily something to be taken up and adapted by people with different cultures/viewpoints. It is possible that the very notion of frameworks as Gee (2016) has written about them and I have taken them up is cultural and would be conceptualized very differently by people with different cultural and social contexts. This is not something Gee (2016) or I have explored deeply, but should be noted as a limitation of this FDA as a theoretical framework.

Neutrality and Tolerance of Frameworks

There is a tension inherent in FDA that Gee (2016) briefly mentioned, but did not explore and which arose as a central tension in operationalizing FDA in the Methods Class in this study. This tension is that of FDA requiring open mindedness to deepen understanding of our own and others' frameworks, but that there is a balance between what Gee (2016) called being "too tolerant" or "too intolerant" of different frameworks. According to Gee (2016), if people were "too tolerant" of different frameworks, people end up the same and end up with a "homogenous mess" which he equated to things like having McDonalds across the world, they are all the same and they are everywhere, which is not very interesting. Based on this example, it seems that Gee (2016) was referring to what would happen if people all took up the same frameworks and did not retain different frameworks. In contrast, if people were "too intolerant" of different frameworks, this would lead to "a shouting match… isolation and sometimes violence" (p. 350). If people would not take up and adjust their frameworks to accept different frameworks, this would lead to people moving away from seeking to understand different frameworks toward trying to prove wrong, devalue, or destroy those frameworks and perhaps the people expressing those frameworks. Gee (2016) did not explain what he thought was the right level of tolerance of different frameworks or how that would relate to the requirement of open mindedness and goodwill in productive engagement between people with different frameworks. In addition, Gee (2016) did not address what would happen or should be done if and when people encounter frameworks that are harmful to others. For example, how open minded should someone be if they encounter a person with a framework that dehumanizes, such as a framework based in white supremacy? Being too tolerant of all frameworks does not only have the consequence of creating a "homogenous mess", but could also mean accepting frameworks that are harmful. As a teacher

educator, being too tolerant or accepting of a PST's framework of white supremacy, for example, can harm people in our class, as well as future students. This tension between requiring open mindedness to engage with and deepen understanding of our own and other frameworks and the need to mitigate harm from the expression of harmful frameworks was central in Methods Class and arose both during design and implementation of Methods Class and during data analysis.

Navigating PST Frameworks Not Conducive to Justice-oriented Teaching

Navigating the tension between valuing all my students (PSTs) and genuinely wanting to understand their frameworks and how they were developed and knowing that some frameworks were not conducive to justice-oriented science teaching was difficult. Just as teaching is not neutral, frameworks are not neutral. Some frameworks are not conducive to teaching in a justice-oriented way and would, when used to shape teaching practices, harm students. For example, a teacher who draws on a framework of the science done by European and European American men as the only correct science and true explanations of the world is likely to apply that framework to their teaching in ways that devalue and erase the science done by anyone else, including students and their community members. It could be possible to support that person in deepening their understanding of their framework of science, how it was developed, and what might be questioned about this framework, especially through engagement with frameworks of science that include science done by community members and indigenous peoples across the world. This is what we (instructors) tried to facilitate in Methods Class. However, if PSTs left Methods Class with a framework of science in which only the science of a narrow group of people was valid, these PSTs were not prepared to be what I would consider to be justice-oriented science teachers. While PSTs' frameworks of science and teaching were welcomed in Methods Class and PSTs were encouraged, even required, to articulate those frameworks, it was

important to recognize that some of these frameworks of science and teaching and/or some claims within these frameworks could be harmful to others. As teacher educators, we (instructors) needed to work to provide opportunities for PSTs to articulate and critically discuss their own and others' frameworks while also mitigating the harm that could be done through public discussion of frameworks based in dehumanizing assumptions and/or stereotypes. As instructors, we both attempted to find this balance for discussion and harm mitigation and we learned through our mistakes and failures at doing this, as I describe in the section on Methods Class Context.

Operationalizing Gee's (2016) FDA for Justice-oriented Science Teaching

In this section, I describe the ways I took Gee's (2016) conception of FDA and operationalized in support of preparing justice-oriented science teachers.

FDA and Justice-oriented Science Teaching

Gee (2016) explained the importance of supporting positive interaction between people with different frameworks through critical discussions toward deeper understanding of those frameworks. In my work, I have provided a way to operationalize this notion of critically discussing and transforming frameworks within teacher education. I have found that PSTs can be supported to deepen their understanding of their own and others' frameworks through opportunities to articulate their frameworks, critically discuss multiple frameworks in context, and reflect on and revise their own frameworks based on this critical discussion. This engagement with and reflection on their own and other frameworks of science and teaching is a key component to developing justice-oriented science teaching practice. Part of this is working to shape the classroom community to go beyond notions of equity as solely access to the current standard curriculum and toward notions of equity and justice in which what counts as science

and success in the classroom is expanded to reflect the ways of being/knowing/doing of students and the local/global community of which they are a part.

I want to be clear that much of what is contained in the current standard curriculum would still be included, but that rather than the goal in the classroom being to transmit one particular set of knowledge and skills as the only correct and useful knowledge and skills in that discipline, this set of knowledge and skills would be discussed as contextualized alongside other contextualized knowledge and skills. Through exploring the contexts of all knowledge and skills, students would gain a deeper understanding of those knowledges and skills and be prepared to make informed decisions as to when and how to apply those knowledges and skills. This is not about, for example, erasing Newton's Laws from the science curriculum, it is about placing those laws in social, cultural, and historical context. This is about learning about ecosystems and food webs and discussing the ways economics shaped the way food webs are discussed in most textbooks and including more relational, complex explanations of food webs that are present in multiple indigenous sciences. And also discussing the affordances and constraints of both ways of thinking about food webs and in which contexts each might be most useful. This kind of science teaching draws on Robin Wall Kimmerer's (2013) idea of the ways multiple cultural sciences complement each other and allow people to more deeply understand the world.

Through operationalizing Gee's (2016) FDA in Methods Class, PSTs can be prepared to recognize, value, and include multiple frameworks of science and teaching in their classrooms. This understanding of and appreciation for multiple frameworks can shape the teaching practices they choose to take up and adapt in ways that honor and include multiple ways of being/knowing/doing which both includes more students and expands the kinds of ideas and experiences all students engage with in school.

How Others Have Taken Up Gee's (2016) FDA

Other scholars have taken up Gee's (2016) FDA as a way to analyze people's frameworks and explain their interactions. In my study, I not only analyze people's frameworks, but also study the ways PSTs analyzed their own and others' frameworks. Frameworks Discourse Analysis is not just for researchers, it is for everyone, and in particular in this study, it is for PSTs and a way to move toward justice-oriented science teaching.

While most papers I found that cited Gee's (2016) FDA simply referred to the paper as an example of discourse analysis and as justification for their use of some type of discourse analysis, a few scholars did draw on Gee's (2016) FDA to identify frameworks. For example, Zilliacus et al. (2017) used FDA to identify frameworks present in curriculum documents over time in their study of discourses on multicultural education in the Finnish national curriculum between 1994 and 2014. Another example is Afroogh et al.'s (2021) paper on empathic engineering education, where discourse analysis was stated as a way for researchers to uncover assumptions by analyzing utterances in context(s). Ogletree and Griffin (2020) studied undergraduate and graduate student narratives on the test scores of Latinx and bi/multilingual students and those of their English-dominant peers to look for the prevalence of asset- and deficit-based discourse. While these studies drew from Gee's (2016) FDA to more specifically identify and analyze frameworks, their focus was primarily on researchers doing the identification and analysis of frameworks rather than participants deepening their understanding of their own and others' frameworks. In my study, I took a two-pronged approach in which I, as the researcher analyzed PSTs' frameworks of science and teaching over the course of Methods Class, and PSTs in Methods Class and during their participation in my study were supported in identifying and analyzing their own and others' frameworks toward deeper understanding of

those frameworks with the goal of raising critical consciousness, valuing and actively including multiple ways of being/knowing/doing, and expanding what counted as science and teaching (i.e., justice-oriented science teaching).

LITERATURE REVIEW

This study is centered around preparing pre-service science teachers (PSTs) to teach science in justice-oriented ways by supporting these PSTs in developing frameworks of science and teaching they can draw from to shape their teaching practice in justice-oriented ways. In this section I reference the need to prepare teachers to work with diverse students and why it is important to do so in justice-oriented ways that do not treat students as needing to assimilate to Western European, white, masculine ways of knowing and doing. I then explain the views of science and teaching that are important for justice-oriented science teaching. I start by describing problems with the universalist view of science that is common in science classrooms and the need for a pluralist view of science. An important part of a pluralist view of science is recognizing social, cultural, historical, and political dimensions of science and teaching and questioning why particular ways of knowing and doing have been normalized. I describe how diversity is a strength in science education and that justice-oriented science teaching is teaching that disrupts injustices through asset-based teaching which values multiple ways of knowing and doing and assumes the rightful presence of students in science education. Finally, I explain that if teachers are to engage in justice-oriented teaching, they need to explicitly define and articulate frameworks of science and teaching that support justice-oriented science teaching. A way that has been posited to support articulation, questioning, and revision of frameworks is that of Gee's (2016) Frameworks Discourse Analysis and I apply this to the preparation of justice-oriented science teachers.

Teaching Diverse Students

The need to prepare teachers to work with diverse students has been well-established (Ladson Billings, 1999, Carter, 2004). Often, when this issue is discussed, it is done so in a

deficit-based, assimilationist way that assumes what is needed is for teachers to learn to help "diverse" students adapt to the mainstream, "correct" way of knowing and doing in schools (Carter, 2004). There have been challenges to this way of thinking about teaching which flip the narrative to focus on changing systems rather than changing young people, such as Ladson Billing's (2006) reframing of the "achievement gap" as an "education debt". In science education, in particular, Mensah and Jackson (2018) have explained the importance of connecting science to the lives and ways of knowing of pre-service teachers of Color as a way to prepare these teachers to connect science to students of Color rather than forcing students of Color to assimilate or be excluded from science. Calabrese Barton and Tan (2019, 2020) have called for disruption of unjust systems and norms through applying the construct of "rightful presence" in science education in which young people are explicitly recognized as rightful members of their science education community and their ideas and lived lives are valued. Morales-Doyle (2017, 2019) has called for science teaching that makes connections between science and history, politics, and social issues explicit sites of inquiry so students can connect with and use science as a tool to actively transform unjust practices, norms, and systems. All of these scholars firmly reject the notion that students, especially students typically excluded from science (e.g., girls, Black, Indigenous, and people of Color) need to change their ways of knowing and doing in the world to align with white, masculine, settler colonial concepts of science in school. To prepare teachers to work with diverse students, we must support them in developing these asset-based, critically conscious (Freire, 1970) views of students, science, and teaching. This requires making visible the political, social, cultural, and historical dimensions of both science and teaching. In the next sections, I explain the need for a shift from a universalist view of science in schools to a pluralist, critically conscious view of science.

The Need for a Pluralist Framework of Science

A common way science is treated in schools (my focus is on a US context, but this also holds true in many places, particularly those with colonial histories) is detrimental to science and to people. Scientific knowledge from Western European, white, cishetero, settler colonial men is treated as the norm or as universal truths to explain the world. In this section, I outline a common argument against teaching science as a static body of facts and explain how this argument falls short of supporting more just science education. Without explicitly engaging with the social, cultural, political, and historical dimensions of science and expanding beyond Eurocentric, cishetero, masculine science, science and science education perpetuate oppressions of white supremacy (Mutegi, 2011, 2013), heteropatriarchy, and colonialism (Bang et al., 2012; Medin & Bang, 2014).

An important thing to note in this section about science is that the idea of what science is and what counts as science is not settled, even among professional scientists and scholars who study the history and philosophy of science (Abd-El-Khalick, 2012). One aspect of science that most scholars discussing science seem to agree on is that the treatment of science as a static body of knowledge in schools does a disservice to science and to students (Wenning, 2009; Abd-El-Khalick, 2012). Wenning (2009), in his article on how scientists know what they know and what that means for teaching science, explicitly stated, "Science is more than a conglomeration of facts, and teaching consists of more than just relating the facts of science. Science is a way of knowing that requires a strong philosophical underpinning (whether consciously sought or unconsciously learned)," (p. 3) to make the point that teachers must support students in understanding the philosophical underpinnings of science. Science was not just a set of facts, but a particular way of constructing knowledge of the world (Wenning (2009). Abd-El-Khalick

(2012) has also outlined common ways of thinking about science and, like Wenning (2009), included that science was composed of generated knowledge and processes of generating that knowledge. Unlike Wenning (2009), Abd-El-Khalick (2012) included the social aspect of science in his discussion of what science is and how it should be taught in schools. Both Wenning (2009) and Abd-El-Khalick (2012) explained that science is tentative, but durable knowledge in that scientific knowledge is always subject to change, revision, rejection and take up of new explanations that better fit evidence. Both scholars agreed that the science knowledge that students would learn was unlikely to change, so while students should understand the tentative nature of scientific knowledge, they should also trust that the information communicated to them in science classes was unlikely to change and should be accepted as accurately explaining the world. These scholars ignored the particular social, cultural, historical, and political contexts of the science that has been valued in schools.

As I mentioned previously, Abd-El-Khalick (2012) did include that science was a social enterprise and that in elementary school, students should know that "different groups of scientists contribute to the development of scientific knowledge" (p. 362), but that was as close as this scholar got to discussing the ways social and cultural contexts interact with science. As he explained, when moving up in grade level, students should learn more about the social norms of science as an institution and that science as a social endeavor makes it objective through processes like double-blind procedures and peer review (Abd-El-Khalick, 2012). This scholar was not concerned with social contexts of scientists, but in describing the social norms of what he saw as the scientific community. The view of science that these scholars shared is a common view of science, which has been termed "universalist", which, as Harding (2006) explained, is the belief that Western science "beliefs and practices did already, or in principle could, form a

coherent, unified representation of nature's order, or at least one that exhibited a harmonious relation among physics, chemistry, biology and other sciences. The knowledge systems of other cultures, it was routinely asserted, were infused with magic, superstition, religion, and other forms of irrationalism and anthropomorphism, making them unreliable guides to nature's regularities and their underlying causal tendencies," (p. 5).

Treating "Western" Science as Neutral and Universal Reinforces Oppressions

A big problem with treating this "Western" or "white" science knowledge as universal is that:

> scientific knowledge is 'manufactured' under constraints much like the production of a culture's other artifacts. Production processes always leave their marks on their final products, and the production processes of science are no exception. Thus, distinctive concerns of particular nations, of imperial and colonial projects, and class, racial, and gender concerns all have left their marks on work in the history of science, (Harding, 2006, p. 8).

Scientific knowledge is created by humans, who are part of particular cultures and influenced by their particular social and political contexts, which in turn influences the science done. Treating science done by one particular group in a particular context as objective and universal hides this relationship between humans and science, making it seem as if the science shaped by particular cultural, social, and political contexts is the only science and any science done in different contexts cannot be science (Harding, 2006). Rather than accept that particular scientific concepts and practices from specific contexts is "settled" knowledge, there has been a push to de-settle science (Bang et al., 2012) and expand what is recognized and included as valid science.

Some scholars focus on de-settling science with an emphasis on recognizing and including the science of African Americans (Mutegi, 2011 and 2013; Le & Matias, 2019), some emphasize native science (Bang & Medin, 2010; Bang et al., 2012; Medin & Bang, 2014; Ryan,

2008), some emphasize feminist science, and others highlight science done by people experiencing poverty (Calabrese Barton, 2000). What all of these scholars have in common is that they reinforce and provide examples of the ways that cultural, social, historical, and political contexts matter in science and science education. Ignoring these contexts, actively hiding these contexts, and presenting scientific knowledge generated by a particular group of people in particular contexts as neutral and universal undermines the goal of science to generate deeper understanding of the world and creates a binary of what is and is not science that upholds white supremacy and heteropatriarchy by othering, devaluing, and erasing the scientific ways of knowing and doing of everyone outside the normalized group.

Le and Matias (2019) explained the problems with this view of "Western" or "white" science, in particular, being treated as universal as resulting in hiding the ways "whiteness has shaped the scientific paradigm," and that "this way of knowing science in the absence of other ways of knowing only furthers whiteness and White supremacy through power and control of science knowledge," (p. 23). Le and Matias (2019) called for addressing this problem by making visible the ways whiteness shapes science and the science taught in schools and changing science culture through dismantling racist ideologies. Le and Matias (2019) highlight two particular racist ideologies that must be addressed in science teaching if we are to stop excluding students of Color by teaching Eurocentric science as universal science. The first ideology is a deficit perspective of students of Color that others people of Color to uphold white supremacy. The second is that of colorblindness. Le and Matias (2019) call for science educators to take actively asset-based views of students and to make visible and address racism in schools so that we can dismantle the system which is based on white norms and practices, which when left implicit, other, exclude, and dehumanize students of Color. In line with Le and Matias' (2019) critique,

Mutegi (2013), in his critique of "Science for All", pointed out that teaching Western, white knowledge as the best science for African American students would be a form of cultural assimilation.

Multiple scholars have provided examples of the importance of recognizing, making explicit, and working with scientific knowledge and practices that are shaped by different cultures and contexts. Bang and Medin (2010) pointed out the importance of native science as science in its own right and not needing to be validated by Western science to have importance and be included in schools. Bang et al. (2012) also explained the importance of de-settling what is counted as science in schools. All of these scholars call for a questioning and de-settling of what has been treated as the status quo in school science, that of treating "Eurocentric ethnoscience" (Medin & Bang, 2014) as neutral and universally applicable for all people and contexts.

Diversity as a Strength in Science Education

The science that is treated as normal, neutral, and universal in schools is scientific ways of knowing and doing of primarily Western European (American), white, cishetero, Protestant, settler colonial men. By treating the scientific ways of knowing and doing of people of these particular contexts and identities as neutral and universal, the scientific ways of knowing and doing of everyone outside these contexts and identities are automatically labeled as "not science". Rather than perpetuating this binary which upholds white supremacy, heteropatriarchy, and colonialism, science educators can teach in ways that recognize, value, and include diverse ways of knowing and doing in science. Calabrese Barton (2000) explained a way to do this in her study on ways pre-service science teachers created multicultural science education lessons through a service-learning experience with young people experiencing homelessness. An

important component of this experience for pre-service teachers was getting to know the young people and their contexts, which allowed them to recognize, value, and incorporate these young people's particular ways of knowing and interpreting the world in the science they did together (Calabrese Barton, 2000). This kind of science education requires a pluralist perspective of science in which multiple ways of knowing and doing in science as based in cultural, social, political, and historical contexts are recognized as part of science overall. This notion of valuing diverse ways of knowing and doing in science supports an approach to science teaching that treats diversity as a strength, rather than something to be overcome so as to assimilate diverse students to the one "correct" way of knowing and doing.

Warren et al. (2004) discuss these ways of thinking about student ideas and their relation to scientific knowledge valued in classrooms. These authors focus on rethinking dichotomies and rather than seeing student ideas as needing to be fixed to align with particular science ideas, teachers can think about continuity between student ideas and science ideas in which student ideas and lived experiences are generative resources for making sense of phenomena in a scientific way (Warren et al., 2004).

Taking up this pluralist view of science as shaped in and by social, cultural, historical, and political contexts can support science teachers in teaching in more justice-oriented ways, as they will recognize the value in working with multiple ways of knowing and doing in science and in supporting their students to do the same and value their diversity as strength (Calabrese Barton, 2000). To teach in justice-oriented ways, science teachers should also recognize that multiple ways of knowing and doing in science are valuable, but that students themselves bring in important ways of knowing and doing that shape science.

A Justice-Oriented Framework of Teaching

I draw from several scholars to define justice-oriented science teaching as teaching that disrupts injustices by treating science as pluralist with social, cultural, historical, and political dimensions (Morales-Doyle, 2017, 2019; Calabrese Barton, 2000), taking an unapologetically asset-based view of students (Tuck, 2009; Freire, 1970), welcoming and valuing multiple ways of knowing and doing (Morales-Doyle, 2019; Medin & Bang, 2014; Mensah & Jackson, 2018), and co-creating norms and meaning through a rightful presence focus (Calabrese Barton & Tan, 2019, 2020).

The Importance of a Humanizing, Asset-based Approach to Science and Teaching

Raising one's critical consciousness helps with recognizing systemic injustices and considering how one might shift one's actions to disrupt these oppressive structures (Freire, 1970). Unfortunately, recognizing oppressive power structures often goes along with identifying the people who have injustices inflicted on them and labeling these people based solely on these injustices. This is a damage-centered view of people and, as Tuck (2009) explains, even when we do this with the intent of recognizing and remediating injustices, we end up doing so by cataloging people's pain, only seeing these people as their pain and as needing to be helped or fixed by others. A humanizing lens focuses on the strengths of people, not solely their pain, and aligns with Freire's (1970) idea that people can only liberate themselves, the oppressors cannot liberate the oppressed and the oppressed and oppressors must love each other to be liberated. Rather than focus on pain, damage and blame, a humanizing approach focuses on the strengths of people while recognizing the current reality. In a humanizing approach, pain, damage, and the problematic current oppressive structures are not the focus, rather a vision for a more just world in which multiple frameworks are recognized, valued, and critically analyzed to better

understand the affordances and constraints of each framework, the context in which it was developed, and the relevance to the current context is the goal. In this way, we work towards an ontologically and epistemologically plural science that is shaped by everyone in each science community, informed by familiar frameworks and expanded through analysis of currently unfamiliar frameworks.

Recognizing and Welcoming Multiple Ways of Knowing and Doing

Justice-oriented science teaching requires that teachers have a pluralist framework of science so they can recognize the existence and value of multiple ways of knowing and doing in science and in classrooms and that a European, cishetero, masculine way of knowing and doing is but one of the many ways of knowing and doing. Teachers must also recognize that these ways of knowing and doing are tied to social, cultural, political, and historical contexts. For example, a European, cishetero, masculine way of knowing and doing can both produce useful knowledge and need to reckon with its ties to oppressive structures of white supremacy, settler colonialism, and heteropatriarchy (Morales-Doyle, 2019; Medin & Bang, 2014). Welcoming many of these multiple ways of knowing and doing as legitimate in science class is a political act of disrupting what has been counted as sanctioned science knowledge and practices in school science and science more broadly in the US. By making the social, cultural, political, and historical contexts of science explicit and connecting science to the ways of knowing and doing of students, teachers can break the cycle of exclusion that communicates to many people, especially people of Color, that science is not something they can do or understand (Mensah & Jackson, 2018). Science teachers can recognize and value multiple ways of knowing and doing in the classroom through a commitment to rightful presence (Calabrese Barton & Tan, 2019, 2020).

Rightful Presence

I draw from Calabrese Barton and Tan's (2019) definition of rightful presence as, "legitimate and legitimized membership in a classroom community because of who one is (not who one should be), in which the practices of that community support restructuring power dynamics toward more just ends through making both injustice and social change visible," (p. 619). Teaching in a way that assumes the rightful presence of students disrupts norms and practices that maintain injustices by actively working with students to co-create norms for participation in the classroom community and make visible the ways students' lived experiences matter in science (Calabrese Barton & Tan, 2019, 2020). Starting with an assumption of rightful presence requires teachers to explicitly acknowledge and work with students to make sense of the social and political dimensions of science and schooling, which is in line with Morales-Doyle's (2019) call for explicitly addressing the political (as well as the historical and moral) in science education. An assumption of rightful presence means that teachers begin with an assumption of the right for students to be in and co-create norms and meaning within the classroom, rejecting the notion that students must change themselves to assimilate to already established ideas of what it means to do science in school. This assumption of rightful presence necessitates a valuing and welcoming of multiple ways of knowing and doing in science education and explicitly addressing the social, cultural, political, and historical contexts in which science is done and learned.

Developing Justice-oriented Science Teaching Frameworks through FDA

In this study, and in our Methods Class, I focused on PST framework articulation, questioning, and revision in part because of the ways frameworks can shape teaching practices early career teachers take up (Thompson et al., 2013). Thompson et al. (2013) found that the

PSTs with clearly defined "critical pedagogical discourses" (similar to what I refer to as "frameworks of teaching") enacted multiple ambitious science teaching practices (the focal practices of their methods class) in innovative ways that fit their context, whereas PSTs with vague critical pedagogical discourses were torn between the contextual discourses of their methods course and their school and ended up enacting practices from each in compartmentalized ways. Finally, the PSTs without critical pedagogical discourses that aligned with methods course discourses would use the terminology of AST without actually enacting the practices.

Based on Thompson et al.'s (2013) findings regarding the importance of articulating well-defined critical pedagogical discourses (or frameworks) aligned with the purpose of focal teaching practices for PSTs to take up and implement these practices in authentic/well-integrated ways, it is important for teacher educators to support PSTs in articulating and critically discussing their frameworks of science and science teaching. PSTs need to have clearly defined frameworks of what science teaching is and its purpose in order to intentionally select and adapt curricula and practices to serve their purpose of science teaching and learning (Thompson et al., 2013). In order to decenter White, masculine ways of knowing in their science teaching, I believe PSTs need to both have opportunities to try out science teaching practices that focus on student ideas and valuing multiple epistemologies and articulate and question their frameworks of science teaching and the social contexts from which these frameworks have been derived (Gee, 2016). In this study, I focused on frameworks of science and teaching that PSTs articulated and how our Methods Class activities supported articulation, questioning, and revision of these frameworks toward more justice-oriented frameworks of science teaching.

I drew from Gee's (2016) Framework Discourse Analysis process as a way to focus on strengths while also gaining a deeper understanding of ourselves, others, and the world. I define frameworks as Gee (2016) does as "...sets of ideas that guide us in what to expect and how to value, assess, or appreciate things and happening in specific situations," (p. 351). These sets of ideas are derived through lived experiences in social and cultural contexts (Gee, 2016). In the FDA process, "the goal is not to reach a definitive truth, to convince someone [they are] wrong. The goal is to deepen our understanding of our own frameworks and other people's frameworks, to raise new questions, and to reflect on changes we might want to make to our frameworks," (Gee, 2016, p. 352). In this process, people 1) recognize frameworks (both familiar and unfamiliar ones), 2) critically analyze those frameworks (identify the context of the development of each framework and the affordances and constraints of each framework in different contexts, question why some frameworks are treated as superior or inferior and why some are familiar to you while others are unfamiliar), and 3) consciously draw from multiple frameworks to make sense of and act in the world (discuss, listen, and learn through the use of multiple frameworks). These are the three major practices PSTs were supported in doing in our Methods Class which was designed to support PSTs to recognize and expand their use of frameworks in science, as well as to support PSTs in developing teaching practices that provide opportunities for their students to recognize and expand their use of frameworks to make sense of and act in the world, or what Freire (1970) call a praxis of liberation, "the action and reflection of men and women upon their world in order to transform it." (p. 79).

METHODOLOGY AND METHODS

This was a case study (Dyson & Genishi, 2005) of the ways PSTs articulated and questioned their frameworks of science and science teaching in my Science Teaching Methods Course (Methods Class), which was designed to support a pluralist framework of science and development of justice-oriented teaching practice. I identified the science and teaching frameworks each PST articulated over the course of Methods Class, how those frameworks related to a pluralist, contextual and justice-oriented framework of science and science teaching, and identified which Methods Class activities were connected to PST articulation and/or questioning of particular claims in their frameworks of science and/or science teaching. The focus of this study was to describe PST frameworks of science and teaching, how those frameworks were developed, how those frameworks related to justice-oriented science teaching, and what role Methods Class activities played in development of PSTs' frameworks of science and teaching. I drew primarily from class artifacts and interviews to identify and describe PSTs' frameworks of science and teaching, changes in articulation over the course of Methods Class, what contributed to these changes, and how this related to a justice-oriented approach to science teaching. I focused on each PST's Science Story (a creative representation of the PST's ideas of science and teaching and what lived experiences contributed to these ideas) which they created and revised over the course of our two-semester Methods Class, as well as their Weekly Reflection Journal entries to identify and describe each PST's frameworks of science and teaching and how those shifted across Methods Class. I also drew from two interviews conducted the summer after Methods Class to discuss with PSTs how they saw their frameworks of science and teaching and how they thought these frameworks had shifted and why.

After identifying PST frameworks, I selected three focal PSTs whose frameworks illustrated the range of a spectrum of ways of thinking about science. I took a deeper dive into these three PSTs' data and the ways their frameworks shifted across Methods Class. I also drew from these focal PSTs' interviews to make connections between Methods Class structure, pedagogy, and activities and PST framework articulation, questioning, and revision. When PSTs referred to particular Methods Class activities, structures, or pedagogy in interviews, their Science Story, or Weekly Reflection Journal, I analyzed the Class Slides and Shared Class Notes Document, and other related artifacts to identify what ideas were shared with the entire class and how those ideas were taken up by each PST.

Context and Participants

This study took place in the context of a two-semester long course sequence of the university's secondary science teaching methods classes for Senior students. This cohort of 17 students was together for the two courses, and 11 of them continued on in the same cohort for methods courses during their fifth-year internship the following year. The methods classes were being taught by a team of graduate student instructors, of which I was a part. This study was conducted in the 2020-2021 school year, which was the first full school year of the COVID-19 pandemic. As such, the entire Methods Class was taught virtually (synchronous classes via a video conferencing platform). This meant we relied on shared Google Documents and Slides for most of our class activities and assignments. We built relationships and rapport in this virtual environment. One of the affordances of this unfamiliar virtual setting was that because most ways of participating in class were done in new ways, PSTs were more likely to try new things. In the first semester (Fall 2020) I worked with a co-instructor and another graduate student who was shadowing the course before she started teaching a methods course in the Spring semester

for pre-service teachers minoring in science. I have co-taught the entire sequence of four semesters of methods courses with a faculty member previously and in the 2020-2021 school year, I co-taught with a first-year PhD student who was a graduate of this teacher preparation program and had returned for graduate studies after teaching 8th grade science for four years in Colorado. While I had experience with the methods courses and the teacher preparation program from the instructor side of things, my co-instructor had experience from the student side of things, as well as his four years of teaching experience adapting the teaching practices he learned in this program.

We all came to this work with a goal of making science education more equitable or, as we have come to call it, justice-oriented. We followed Calabrese Barton et al.'s (2020) definition of justice-oriented disciplinary teaching as teaching that centered and amplified "identities and cultural practices", "the political and humanizing dimensions of teaching/learning", and "foregrounds supporting students in developing critical awareness of and strategies for navigating and transforming" the social world (p. 479). My co-instructor, Timothy, and I were both White teachers and recognized that our work of uncovering and naming Whiteness and actively seeking out, valuing, and incorporating multiple voices, and working to disrupt Whiteness in science education was a long-term commitment and one we were still learning how to do well. Because of our commitments, we focused on shaping our methods classes around not only science teaching practices, but justice-oriented science teaching practices and on supporting our PSTs in articulating their own ideas of science and science teaching so they could be named and discussed in the context of other, different ideas of science and science teaching. Our third instructor, June, was an invaluable asset to our planning and implementing of this course as she had been steeped in justice-oriented teaching practices and ideas related to multiple

epistemologies and agency for the last few years of her graduate work. She was also an international student and a woman of Color and brought her own unique perspective and experiences in teaching and teacher preparation to the class. Together, the three of us worked to create a science teaching methods course that supported our PSTs in articulating their ideas of science and science teaching, critically discussing the purposes of science and science teaching, critically questioning and reflecting on their own and their peers' teaching practices. Timothy and I continued this work during the Spring Semester after June left to teach a separate course. It is important to note that all of these PSTs were White-presenting. The fact that there were no PSTs of Color in this methods class was representative of one of the systemic problems in teacher education, that we do not recruit or prepare enough teachers of Color, and in fact, in many places, through admissions policies actively exclude potential teachers of Color (Kretchmar & Zeichner, 2016). While, PST recruitment was beyond our purview as graduate student instructors, we did see an opportunity to work as White teacher educators, who did not experience the added burden of many faculty of Color, to help our White PSTs to identify whiteness in their ideas of science and science teaching and work to disrupt this, or as Bang et al. (2012) said, to "desettle" these expectations in science that Eurocentric, masculine epistemologies are the only science epistemologies that count in school.

Instructors as Co-learners with Each Other and PSTs

Timothy, June, and I approached our work together as an opportunity for co-learning. By co-learning, I mean that we saw ourselves as always able to deepen our understanding of science and teaching through discussing readings, ideas, and experiences we each brought to the class. Similarly to the way Dewey (1916) conceptualized communication, I think about learning and communicating as being dialogic and done through shared meaning making. As co-learners, no

one was the end all be all expert, everyone had useful ideas and experiences to share, discuss, and learn from.

The ways that the three of us had been positioned when being put together as a teaching team could easily have been used to create a hierarchy that would have shaped our interactions and the way Methods Class was taught. I had previously taught the Methods Course sequence with a faculty member and was established as an experienced teacher educator. Timothy was a first-year graduate student so he was new to both graduate school and teacher education. June was a graduate student shadowing the course to gain experience with how a methods course was taught before solo teaching a semester-long methods class in the Spring. I did not want to be positioned as in charge of the class or as the expert in this class. I knew enough about teacher education to know how much I did not know about teacher education. June and I had been working together on a research project for the previous two years and I deeply respected her as an educator and a researcher. I did not know Timothy, but I knew he had gone through the university's teacher education program himself and was coming to graduate school after teaching middle school science for four years. Based on this experience alone, he would have important insights into the program and the ways he experienced transitioning from the program to the classroom. We all had valuable experiences and ideas to contribute and I wanted us to be a teaching team with shared goals we would work toward together. Timothy and I met several times during the summer before Methods Class began to get to know one another, talk through our views on teaching and teacher preparation, and discuss the structure and goals for Methods Class. Later in the summer, we learned that June would be shadowing Methods Class and we welcomed her into these planning sessions. We knew relationship building would be important in Methods Class and we went through relationship building activities together before

implementing those activities with PSTs in the Fall. We met multiple times a week to plan for and reflect on activities and PST ideas and interactions. As a result of this structure, we were a team. We build off of each other's ideas. We learned from each other's perspectives.

As co-learners, we (instructors) often began planning meetings with an observation of something we had found interesting either in a previous Methods Class session or that we had come across in our own coursework, reading, or research experiences. We would discuss this interesting idea and whether/how it connected to our goals in Methods Class. If the idea seemed useful in working toward Methods Class goals, we would discuss how it could be incorporated in the next class session or a session later in the semester or possibly the following semester. While we had a fully planned semester, our syllabus and our course were living and dynamic as we continually adjusted based on PST interactions, ideas, and needs, as well as current contexts/events. As instructors, we were exploring what is and should be the purpose of science and science education, what equity and justice looked like in science and science education, what was the purpose of teaching (science), and the role whiteness played in science and teaching as well as our own relationships with whiteness. As we explored these ideas, we discussed and shared with each other and approached them from the perspective of teacher educators. We brought these ideas to Methods Class in ways our PSTs could explore as they developed their science teaching practice. Being co-learners was a great strength in making our teaching flexible and drawing from multiple experiences and perspectives.

Addressing Whiteness

It must be stated that, especially for Timothy and me, being novices in the study of whiteness was a weakness in the way we taught Methods Class. While we strove to continue learning and to support our white-presenting PSTs to explore whiteness, how this manifested in

science and schooling, and their own relationship with whiteness, we did this mostly implicitly. Looking back on Methods Class, both Timothy and I would address whiteness more explicitly, especially in the second semester after we had built strong relationships as a class and had laid the groundwork for discussing multiple frameworks, cultures, and identities. At that point, our PSTs were ready to discuss whiteness and by not addressing and naming whiteness explicitly, we did them a disservice. We allowed whiteness to remain implicit when naming whiteness and discussing it would have supported PSTs in better understanding what whiteness was, how whiteness maintained and protected itself, especially through school structures and procedures, and how they as teachers could push back on the power dynamics maintained by whiteness.

As we, as instructors, raised our critical consciousness throughout Methods Class, we also noticed ways that we could prevent/mitigate harm in Methods Class and how our lack of foresight and experience could have very negative consequences for our current PSTs, for PSTs of Color, for PSTs' future students, and for June as a woman of Color. As we supported our PSTs in addressing the political, historical, cultural, and social contexts of science lessons, we (instructors) also learned how we as teacher educators could better support PSTs to create lessons that did not repeat, present, or publicly and unexpectedly surface harmful stereotypes of people. While we emphasized that PSTs should be prepared to address the political, historical, social, and cultural contexts of their lessons, we (instructors) were often reactionary in providing PSTs with tools to mitigate harm that might be perpetuated as these contexts were discussed and biases and stereotypes were surfaced in student participation.

An example of this reactionary way of addressing the sociopolitical in teaching science occurred during Felix's team's Macroteach (a 6-day long unit planned and implemented with peers by small groups of PSTs). During one lesson in this Macroteach, harmful stereotypes of

Indigenous Peoples were surfaced. We (instructors) discussed this situation with the Macroteach team and the whole class and later implemented a two-day lesson on how to facilitate critical conversations. Instead, we (instructors) should have anticipated that PSTs would need support in the form of strategies to surface ideas related to such critical conversations without perpetuating harm. We should have implemented our critical conversations lesson before any Macroteaches were implemented and we should have asked PSTs to identify places for critical conversations in their Macroteach unit and which strategies they planned to use to mitigate harm and facilitate critical discussion of the topic.

This is a lesson we learned as teacher educators that was tied to our own whiteness and lack of foresight, which could have been even more harmful in a more diverse class setting. We were able to correct our oversight without direct harm coming to our PSTs, but that was due to the composition of our class and should not have been an issue in the first place. We (instructors) learned the same lesson Felix did when he said that his first reaction to surfacing stereotypes of Indigenous peoples was to simply have the class talk about these stereotypes and that he later realized that asking students to share more about their ideas of Indigenous peoples without any sort of preparation or strategies to support critical thinking/discussion without exposing others to negative, harmful ideas was "rolling the dice on students' well-being" and that he was not ok with this. We (instructors) had done something similar as we asked PSTs to implement their Macroteach units drawing from two frameworks without providing explicit support/strategies to mitigate harm. We had rolled the dice on students' well-being. We all (instructors and PSTs) learned that we needed to be better prepared so as to do our best not to perpetuate harm and to support critical discussion of the political, historical, social, and cultural contexts in science lessons. There is danger in addressing science in this way, but there is also danger in pretending

these contexts do not exist and that science is neutral. A hugely important lesson we learned was that we must address political, historical, cultural, and social contexts in science lessons, but we must do so responsibly and actively take steps to mitigate harm that can come from surfacing harmful ideas based in white supremacy, heteropatriarchy, and settler colonialism that are endemic in our society.

Co-designing Methods Class

We shared our experiences and ideas in Methods Class with PSTs and we modeled working together and brainstorming solutions to sticky situations that came up in class. This sort of modeling simply consisted of us doing our planning and discussing in ways PSTs could listen and participate as these were things we commonly did anyway. Starting out with the intention of working together as a teaching team facilitated our co-design of Methods Class as instructors and our inclusion of PSTs in the co-design of Methods Class as well.

An important tenet of Methods Class and our (instructors) teaching philosophy was that everyone in the class had important ideas and experiences to share. Tied to this was the idea that no two teaching practices are identical; everyone must develop their own teaching practice which makes sense for them and can be applied and adjusted to suit their context and particular students. Based on these tenets, we (instructors) designed Methods Class with the idea that we were facilitating PSTs in determining and building their own teaching practice through articulating and critically discussing their goals/purpose of science/teaching and exploring practices and strategies which could be applied in service of those goals/purpose. Our role as instructors was not to present PSTs with a set of practices to emulate, but to support articulation, discussion, reflection, and revision of PSTs' teaching philosophy and explicit connection between that philosophy and teaching practices.

One of the ways that we included PSTs in co-design of Methods Class was through continual, iterative norming and goals generation. Once we had co-generated goals for Methods Class, we discussed what norms would help us work toward those goals. We (instructors) provided examples of norms and PSTs worked in small groups and then as a whole class to decide on norms for participation in our class. We (instructors) included multiple ways to check in on how PSTs were feeling in class in terms of participation and progress toward goals. After each check-in (e.g., short survey, Weekly Reflection Journal prompt, class discussion), we (instructors) would discuss PSTs' responses and propose some adjustments to norms for PSTs to discuss (i.e., accept, question, adjust, propose new norms). We continued this iterative process across the 2 semesters such that our class norms were always connected with the realities of our class and our goals and that these norms were dynamic and shaped by all class members. This iterative norming was part of our (instructors) broader commitment to creating a classroom community built on healthy relationships. This was important to us (instructors) in every class we taught and was especially important in the 2020-2021 school year during which classes were held on a virtual platform rather than in-person. Regardless of the virtual nature of the course, we (instructors) worked to build community with PSTs. Through humanizing practice and co-creation of Methods Class, we created a strong classroom community of instructors and PSTs all working to develop their teaching practice.

3 Focal PSTs

I selected three PSTs whose frameworks of science at the end of Methods Class represented the opposite ends of the spectrum of science frameworks and one point near the middle. These PSTs started with different frameworks of science at the beginning of Methods Class, but all three began closer to the end of the spectrum that aligned science with truth. These

three PSTs represented three different trajectories of science frameworks and the ways their frameworks of science teaching were articulated, questioned, and adjusted/reinforced also represented both alignment of science and teaching frameworks and divergence of science and teaching frameworks. These three PSTs' frameworks provided an interesting picture of the connections between science and teaching frameworks across PSTs.

I have selected one PST whose framework was situated on the objective truth end of the spectrum and stayed there (Alice), one PST who started Methods Class questioning the idea of science as objective truth and articulated a detailed and nuanced explanation of how science was used and created by humans (Willow), and one PST who started Methods Class on the objective truth end of the spectrum and throughout Methods Class shifted to the science as relative and contextual end of the spectrum (Felix).

By the end of Methods Class, these three PSTs provided an example of each of the opposite ends of the spectrum and a middle point on the spectrum. To be clear, there is not a correct place on the spectrum. There are different ways of thinking about the world, what science is, and how humans and science are related. All of these ways of thinking about science, truth, and humans offer affordances and constraints to the person taking up each particular way of thinking.

Methods Class Overview

Our Methods Class refers to a two-semester-long course with a cohort of secondary science pre-service teachers. Methods Class was the first half of a four-semester-long sequence of courses focused on preparation to teach science in middle and/or high schools. The expectation was that, after completing our Methods Class (the first 2 semesters), PSTs would complete their undergraduate degree and go on to a year-long Internship in a middle or high

school with a mentor teacher and finally to become certified to teach. Methods Class was the first teaching-related class in the program that was discipline-specific.

Typically, a primary goal of the Methods Class was to support PSTs in learning to plan and implement a lesson in the first semester and a unit in the second semester. We maintained this goal in our Methods Class, but situated it within the goal of learning to teach in justice-oriented ways. This included building relationships with students to better understand their contexts and support student sensemaking related to explaining relevant phenomena. Supporting student sensemaking required recognizing multiple ways of being/knowing/doing (i.e., frameworks) and critically discussing these in class. Recognizing and actively including multiple ways of being/knowing/doing required PSTs to raise their critical consciousness to understand and question the political, historical, cultural, and social contexts that shaped social norms and structures. We supported PSTs in developing justice-oriented science teaching practices by focusing on development of teaching philosophy that recognized and valued multiple ways of being/knowing/doing and connected this to teaching practices that could be used to enact this teaching philosophy.

We drew from Gee's (2016) Frameworks Discourse Analysis, critical humanizing teacher preparation (Carter Andrews et al., 2019) and asset-based (Tuck, 2009) notions of working with people to design Methods Class activities that would support PSTs in recognizing, critically discussing, and incorporating multiple frameworks into their teaching. We drew from the Ambitious Science Teaching framework (Thompson et al., 2013) and Calabrese Barton et al.'s (2020) approach to justice-oriented STEM pedagogy to provide possible teaching practices for PSTs to draw from.

PSTs' as Co-designers of Methods Class

We worked to structure our Methods Course so that it aligned with one of our core beliefs as instructors that students should be respected as autonomous people with valuable ideas and goals relevant to their learning. As part of this belief, we began each semester by co-creating goals for the class with PSTs. The co-created goals for each semester can be found in Figure 1 and Table 1. These goals were centered around developing practices that would support justice-oriented science teaching. In the Fall Semester, our goals were things like planning and implementing lessons that built from and integrated student ideas, creating a community of practice with students, and reflecting on and developing an equitable philosophy of teaching. In the Spring Semester, our goals were to continue to develop the teaching philosophy and we explicitly included ideas of taking an asset-based view of students, creating a classroom culture driven by student ideas, developing and implementing unit plans in equitable ways. The goals focused on developing and reflecting on a science teaching philosophy was one way we tied articulating and reflecting on frameworks of science and teaching to a more well-known aspect of learning to teach. All of these goals were co-created and represented a consensus of what we (instructors and PSTs) wanted to work toward together each semester.

Figure 2. Fall Semester Co-Created Goals for the Class

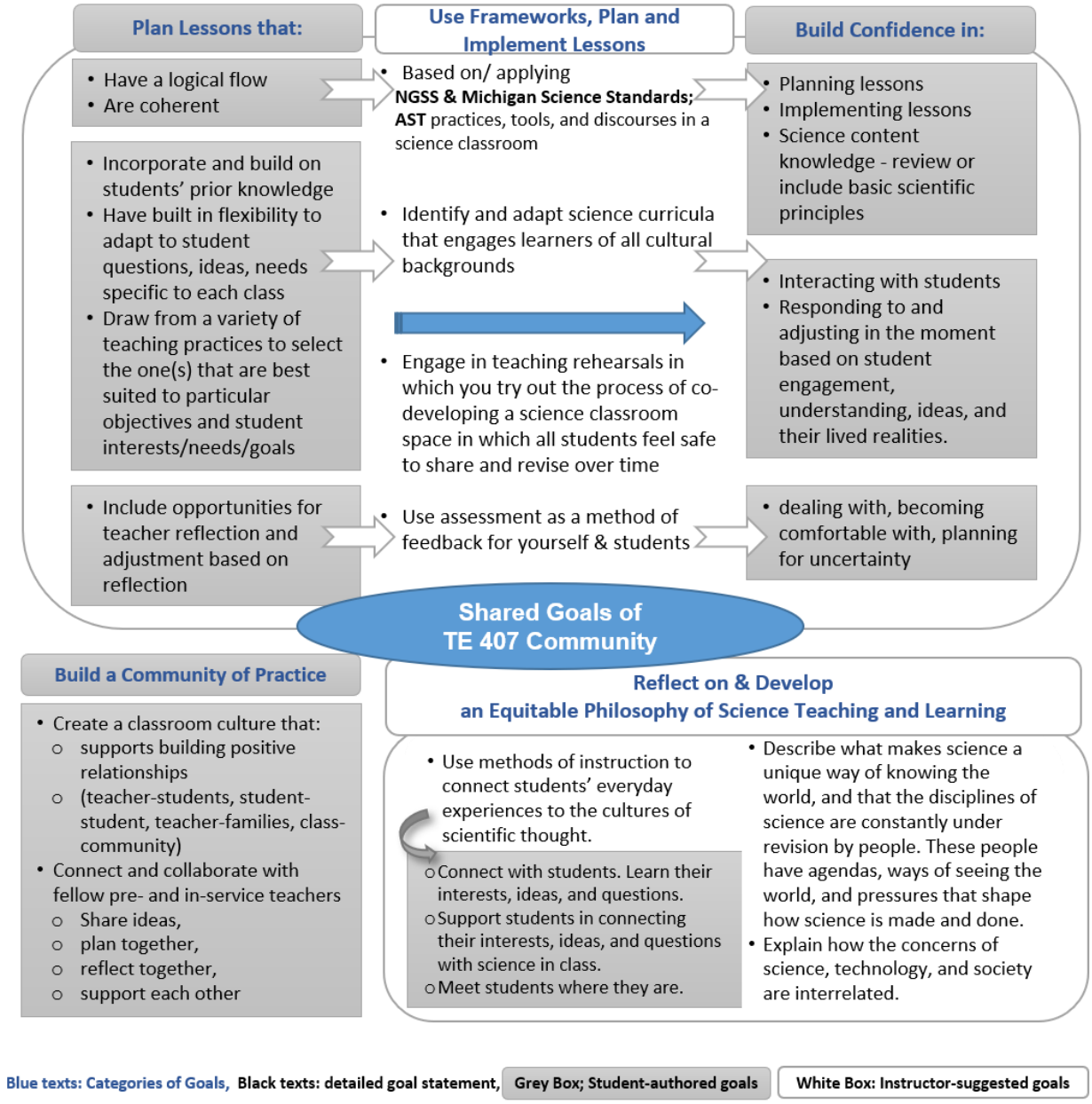


Table 1. Spring Semester Co-Created Goals for the Class

Goal	Sub-goal
Develop your Teaching Philosophy	Develop your purpose of science teaching and learning
	Continue to examine, reflect on and try out equitable practices/ practices that define

Table 1. (Cont'd)

Goal	Sub-goal

Develop your Teaching Philosophy (Con't)	Develop and follow an asset-based view of students
	• Positive view of students. Assume that all students bring prior knowledge, experiences, ideas that are valuable and useful.
	• Recognize that different students bring different knowledge and experiences from different communities. Different does not mean worse.
	• Focus on celebrating and building from what students bring rather than holding all students to the standards of one particular culture.
	• Look for what students bring (prior knowledge and experiences)
	  ○ E.g., students who speak Spanish bring that knowledge, NOT-this student doesn't speak English and needs to learn English
	  ○ E.g., Ms. T in Anatomy classes, she doesn't lecture symptoms of diseases, she asks students for their experiences first.
	  ○ E.g., **have conversations with students.** Need space students are comfortable sharing so they can bring in their experiences. Creating this space can take more or less work depending on students' previous experiences.
	  ○ Get to know your students with the mindset that they have good things to share with you.
	Be careful with assumptions about the value of students' resources, knowledge, and experiences

	Identify, examine, reflect on and support how identities (personal, student, science) interact within a school system
Create a Classroom Culture Driven by Student Ideas	Building relationships through a variety of avenues, such as co-constructing norms and expectations with students, focusing on communication (transparency, consistency, flexibility)
	Recognizing and examining existing power structures, and disrupting and transforming them where necessary
	Recognizing and analyzing different roles for teachers and students in the classroom or in science

Table 1. (Cont'd)

Goal	Sub-goal
Develop and Implement Unit Plans	Drawing from and creating curricula centered around objectives and the Next Generation of Science Standards
	Developing big ideas, phenomena and driving questions, designing assessments that make student thinking visible to classroom community
	Planning and implementing the four practices of AST in equitable ways
	For each of the following, consider who and what has been erased from the typical body of science knowledge and work to bring these into your lessons
Try out Particular Interactions and Practices	Work on individual in-the-moment practices with teacher-teacher, student-student, student-teacher, teacher-system, etc. For more examples, see the resource sheet.

A foundational goal of our Methods Class, as instructors, was for PSTs to articulate their ideas of science and science teaching and the experiences that led to the development of those ideas. We created a variety of assignments and activities in support of this goal (please see a list of major assignments and their differences across semesters in Table 1). PSTs created and revised their Science Story, which was a creative representation of their ideas of science and science teaching and the experiences that led to those ideas. PSTs created their Science Story, shared and discussed these with peers, and revised them based on peer and instructor feedback over the course of the year-long Methods Class. PSTs also wrote weekly journal entries based on instructor-created prompts intended to provide PSTs with a place to reflect on their current thinking about what counts as science, what the purpose of science teaching should be, and how science should be taught. In addition, PSTs planned, implemented, and reflected on three "Microteaches" or 20-minute peer teaching experiences, each centered on an AST practice such

as eliciting student ideas. During the second semester, PSTs worked in small groups to plan, implement, and reflect on full units based around a focal system and anchoring phenomenon that would be approached using at least two different framings of the science and the phenomenon. Each group had six days (90 minutes each day) to teach a unit with their peers acting as students. Before implementing their unit, PSTs did research on their focal system and this research had to draw from at least four different sources of information: journal articles, professional documents, traditional/community wisdom, and other media. In this way, we intended to reinforce the idea that valuable information for understanding systems comes from multiple sources. PSTs then shared their information with their small group and identified the framings of each piece of information. PSTs wrote up a gapless explanation of their chosen phenomenon drawing from at least two different framings. Once the groups had done this, they could begin to plan their unit, which needed to explicitly include at least two framings for understanding the phenomenon.

Table 2. Major Methods Course Assignments and Differences by Semester

Assignment/Activity	**Fall Semester**	**Spring Semester**
Science Story	• Create a representation of PST's ideas of science and science teaching and experiences that led to these • Share and discuss with peers • Revise based on peer and instructor feedback	• Revise and build on previous representation on PST ideas of science and science teaching and experiences that led to these • Analyze ideas and experiences through 4 focal lenses: identities, culture, intelligence, success • Share and discuss with peers

Table 2. (Cont'd)

Assignment/Activity	Fall Semester	Spring Semester
Peer Teaching	Microteaching • three 20-minute lessons • Each based on 1 AST practice • Includes written plan and reflection	Macroteaching • One 6-day-long unit • Goes through an entire unit cycle (plan, elicit student ideas, support students in building on and expanding ideas, create evidence-based explanation of phenomenon) • Includes written plan and reflection • Requires prior research focused on multiple sources of information and explicit identification of multiple framings of science • Includes in-the-moment pauses, discussions, and adjustments of instruction
Weekly Reflection Journal	• Weekly opportunity to document thoughts on prompts created by instructors related to science and science teaching	• Weekly opportunity to document thoughts and questions related to science and science teaching • Directly related to the 4 focal lenses (culture, identities, success, intelligence) and weekly class topics • Addressed weekly by instructors and used to adjust/inform class assignments/activities
Critical Friends Groups	• These are supportive reflection groups that meet after each peer teaching event and twice to discuss Science Story	• These are supportive reflection groups that meet after each Macroteach to address a problem of practice related to analysis of student work

Recognizing and Critically Considering Multiple Frameworks

We (instructors) operationalized Gee's (2016) Frameworks Discourse Analysis (FDA) in Methods Class by supporting PST participation in three types of activities: (1) articulating their frameworks of science and teaching, (2) critically discussing multiple frameworks of science and teaching, and (3) reflecting on and revising their frameworks of science and teaching. These three types of activities were designed to support PSTs in more deeply understanding their own and others' frameworks of science and teaching toward developing justice-oriented teaching practice. If PSTs considered the contexts and affordances and constraints of multiple frameworks, including their own, they would be more likely to recognize the existence of multiple frameworks, ask themselves if an unexpected idea or action was the result of a differing framework (rather than immediately labeling this idea/action as wrong), and potentially actively include multiple ways of being/knowing/doing in the classroom. There is overlap across activities within the three types, but what follows are examples of activities in each of the types they were primarily used to support.

Activities to Articulate their Own Frameworks of Science and Teaching. We primarily supported PSTs in articulating their frameworks of science and teaching through the use of the Science Story, the Weekly Reflection Journal, and padlets. The Science Story was a type of critical autobiography specifically related to each PST's relationship with science and teaching. PSTs were asked to express their ideas of science and teaching and the experiences which had shaped those ideas. This representation could be done in any format as long as it was shareable with instructors and peers and could be worked on and adjusted over time. PSTs created their first edition of their Science Story and shared them with each other in small groups as an opportunity to provide and receive constructive feedback about the clarity of ideas, as well

as learn about each other's ideas and experiences. PSTs then submitted a first edition of their Science Story to instructors and received individual feedback, primarily in the form of questions about ideas and connections to experiences and values. In addition to this individualized feedback, instructors provided a set of guiding questions to refer to as PSTs revised their Science Story for the end of the Fall semester.

Revisions of the Science Story included consideration of activities and experiences during the Fall semester and how they related to the ideas in the Science Story. PSTs received individual feedback from instructors on their second edition of their Science Story and instructors provided guiding questions to consider across the Spring Semester as PSTs revised their Science Story again. Instructors also designed multiple activities to support PSTs in critically discussing and reflecting on their own and others' frameworks, which were useful in revisions. PSTs also responded to instructor-provided prompts in their Weekly Reflection Journal. This was a space for PSTs to state their ideas, try out new ideas, and/or question new/old ideas. This also became a space for some PSTs to pose questions of instructors or ask for advice.

We (instructors) also used several forms of modeling for PSTs to articulate their ideas individually and in small and large groups. Often these were in the form of a padlet with a prompt for PSTs to respond to. All of these activities provided ways for PSTs to articulate their ideas of science and teaching and where those ideas had come from.

Critically Discussing Multiple Frameworks of Science and Teaching. We (instructors) designed multiple activities across the two semesters to support PSTs in critically discussing multiple frameworks of science and teaching and connecting those frameworks with teaching practices. We provided PSTs with scenarios depicting interactions between teachers and students with different frameworks and provided guiding questions to support discussion of the outcomes

of these interactions and the ways science was represented. We provided PSTs with examples of ways people's frameworks shaped particular science knowledge and/or practices. Reading these scenarios was accompanied by space to reflect in writing individually, in small groups with peers, and with the whole class. We also provided multiple opportunities for PSTs to represent, share, and discuss how they were thinking about what science was, what good teaching was, what the purpose of teaching was, how to enact a purpose of teaching through practice, and how concepts of identity, culture, intelligence, and success related to science and teaching. We also moved from discussion and modeling of ideas to discussion, modeling, and trying out of practices.

To connect discussions of multiple frameworks with the practice of teaching, we (instructors) modeled lessons that actively included multiple frameworks of science and teaching/learning. We also provided PSTs with lesson and unit plan guidelines that required the inclusion of social, cultural, and historical contexts of science and planned activities. We provided PSTs with opportunities to try out (i.e., design, implement, reflect on, and adjust) teaching practices in ways that actively included multiple frameworks of science and teaching. Each of these opportunities (e.g., instructor modeling, PST planning, and PST implementation and reflection) to identify and integrate multiple frameworks in science teaching was accompanied by small group and whole class discussion of the goals/purpose of each lesson/activity, the outcomes of each lesson/activity, the role of frameworks/contexts in the way the lesson/activity was designed, implemented, and taken up by students, and what might be adjusted.

Reflecting On and Revising their Frameworks of Science and Teaching. As noted in the previous examples of activities, reflection was integrated into every part of Methods Class.

Each activity had a component of reflection and revision. The most obvious places where we saw revisions were in the multiple editions of the Science Story, in shifting ideas that were shared in Weekly Reflection Journal entries over time, and in lesson and unit plans and reflections over time. This emphasis on individual and group critical reflection and revision was a core part of Methods Class and a key part of more deeply understanding frameworks. This continual reflection and revision supported PSTs in being explicit about what their ideas of science and teaching were, why they believed those ideas, what practices would support enactment of those ideas and why. This kind of continual, practical, critical reflection is a foundation of the teaching profession as no two classes or contexts are identical and teachers must continually adapt their practice to best serve their students and communities. This kind of continual reflection and revision also supported PSTs in questioning what they believed and why so that they could better understand their frameworks and consider those of others.

Positionality Statement

This study and the Methods Class it is based in, have been shaped by my own ideas of science and science teaching. Science and science teaching shape and are shaped by the people who engage in them and the contexts of that engagement. My ideas of science as a way of understanding, explaining, and making decisions about acting in the world and science teaching as supporting students in engaging with multiple ways of observing, interpreting, explaining the world and applying these knowledges and practices to guide their decision-making come from my own experiences with science and what it has meant to me and my experiences learning and teaching. In Appendix A, I share a more detailed explanation of how my ideas of science and science teaching developed through my Science Story. What follows is a summary of that story.

My relationship with science has shifted over time and across experiences, but one thing has remained consistent; the purpose for pursuing scientific knowledge has shaped the way that pursuit has taken shape. As a child, my purpose was to understand the human body so I could find treatments and cures for diseases, so I spent my time studying human body systems and how they interacted with disease. In school science, the purpose was to continue learning about systems interactions, partly because I found these systems interesting and partly because I was good at it and liked the feeling of understanding and explaining concepts that were described as difficult for many people.

In college, I started to question why I was pursuing science. I enjoyed learning and understanding how systems interacted, but simply enjoying knowledge for knowledge's sake was not enough. The obvious path was medicine, but that didn't appeal to me. I wanted to continue learning and, as far as I knew, being a doctor meant working out of an office and diagnosing patients with colds or performing surgeries. Hurting people to help them and potentially accidentally doing lasting harm sounded horrible to me. Being a doctor wasn't about learning science. When I tried out medical research, I realized that I enjoyed interacting with people too much to want to work in an isolated lab, especially one that used animals.

When I started teaching, the purpose of pursuing scientific knowledge was to create a coherent, reasonable and interesting story about how some part of the world worked. This was what I loved, but it was still about my doing the majority of the sense-making, using scientific knowledge that already existed, and transmitting that completed story to students. When I started teaching in Mendota, California, I moved toward providing opportunities for students to seek out and interpret scientific knowledge to create stories for themselves, but we were still primarily using scientific knowledge that already existed. I would like to see what science education would

look like if the purpose were to understand existing scientific knowledge and where it came from, but also to explore relevant, local phenomena and issues in a way that promoted students' generation of scientific knowledge. This type of science education would provide opportunities for students to explore and generate knowledge about their environment in a systematic and empowering way. Students would not only learn about science; they would contribute to science.

This was the motivation for shaping Methods Class around PSTs articulating their own ideas of science and science teaching, critically discussing these ideas and ideas that might be new or unfamiliar to them, and drawing from multiple ideas of science and science teaching to shape their teaching practice. If science teachers are to recognize, value, and support the building from and expansion of students' ideas and experiences in science, then PSTs must be given opportunities to think through their own ideas and where they came from and to explore currently unfamiliar ideas.

PSTs must be given opportunities to think through the cultural, social, political, and historical factors that shape our ideas and practices, including science and teaching. I have been lucky enough to experience some of these opportunities throughout my schooling and teaching career, but I think I could have been a better teacher from the beginning if I had had opportunities to explore and critique my own ways of seeing the world with regard to science and teaching, what I thought science and teaching were, what their purposes were, and how they could be done. This is what I have tried to do for my PSTs in Methods Class. This is especially important because the way science is typically taught is as an acultural, acontextual set of knowledge and practices. This treatment of science excludes people from engagement with science and devalues and erases science that does not align with the White, masculine, heteronormative science we have labeled as simply "science." As a White, cis-gender,

heterosexual woman who has lived in three countries (including the U.S.), I have both been othered in school/science and have done the othering. My goal in Methods Class is to support PSTs in recognizing, questioning, and drawing from multiple frameworks of science and teaching so they are less likely to perpetuate science teaching practices that position White, masculine, heterosexual ways of knowing and being as superior and a requirement for participating in science.

Data Generation

The data generated with the PSTs were artifacts created during the two-course sequence of methods classes and two semi-structured interviews with PSTs at the end of the school year.

Artifacts

PSTs created a range of artifacts as part of our methods classes together. These included artifacts that were designed to support PSTs in articulating their frameworks of science and science teaching, such as the "Science Story" and Weekly Reflection Journal. (See Table 3 for a description of the artifacts.) The "Science Story" was a representation of each PST's ideas of science and science teaching and what experiences led to their ideas. This Science Story was revised twice over the course of the two classes as PSTs added ideas and experiences from their classes, their field experience, and outside of the teacher preparation program. This Science Story represented an articulation of each PST's framework of science and science teaching. PSTs responded to weekly reflection prompts in a digital journal. These prompts asked PSTs to reflect on activities in class, their approximations of teaching, as well as their peers' approximations of teaching.

Interviews

I conducted two individual semi-structured interviews with PSTs at the end of the 2020-2021 school year to ask them to share their current ideas of what it meant to be a science teacher, why they wanted to be a science teacher, and how their experiences in Methods Class related to their ideas of science teaching (please see the interview protocol in Appendix B). I chose semi-structured interviews because while I have some focal areas I would like to discuss with each PST, I see interviews as conversations in which the participants (i.e., the researcher and the study participant) co-construct meaning (Hoskins & White, 2013) and a semi-structured interview provides necessary flexibility for such conversations. I referred back to each PST's Science Story and weekly reflections to tailor the interview to each individual PST. In particular, I was looking for PSTs' ideas of what counted as science and why, as well as what it meant to teach science and why. I shared the ideas I noted in each PST's Science Story editions, Weekly Reflection Journal entries and that I had noted in memos throughout Methods Class and during discussions with my co-instructor, Timothy. I shared these ideas with the PST by showing an excerpt of the relevant artifact and asked the PST to reflect on what they were thinking and feeling in that moment, how they were thinking about it now, and what this meant for the kind of science teacher they saw themselves being in the future.

Interviews were primarily a way to reflect on ideas from Methods Course, ask for clarity, and discuss how PSTs were thinking about science and teaching after having a few weeks to reflect. I saw these interviews as extensions of how PSTs were thinking about science and teaching in Methods Class as the interviews took place a relatively short period of time after Methods Class had ended. Any new ideas or revelations that emerged during the course of the interviews were built upon the frameworks PSTs had already articulated and revised during

Methods Class. There were some new thoughts or recognition of or renaming of "older" thoughts that came up in interviews, but there were relatively few of these as I treated the interviews as reflections upon Methods Class and therefore expressions of ideas that were relevant in Methods Class, but I could not have seen clearly by relying solely on analysis of Methods Class artifacts. None of these new ideas/revelations occurred during interviews with the three focal PSTs.

Analytic Framework

In my data analysis, I focused on identifying PST frameworks of science and teaching by looking for ways PSTs expressed how they were thinking about what science was and what teaching was, as well as from which contexts and experiences they had derived those ideas. As I was interested in how likely PST frameworks were to support a justice-oriented approach to teaching, I focused my analysis on science and teaching ideas connected to constructs related to justice-oriented teaching.

Science Frameworks

To analyze data for evidence of PSTs' frameworks of science, I focused primarily on expression of ideas related to science as a universal way of explaining the world or a pluralist, contextual way of explaining the world. Evidence of a universalist framework of science was the maintenance of connections between humans and science as implicit or denial of their existence or the need to recognize these connections. For example, a PST might state that science is neutral or the same regardless of context or the person who did the science. In addition, in a universalist framework, this "neutral" science is represented as truths about the world that can be applied broadly, regardless of context. A more pluralist, contextual view of science would be evident in statements about multiple ways of thinking about evidence or doing science, ways of knowing or doing as cultural or social. In addition, in this pluralist, contextual view of science, scientific

knowledge might be represented as useful knowledge and processes to generate knowledge that are tied to social, cultural, political, and/or historical contexts.

Teaching Frameworks

To analyze data for evidence of PSTs' frameworks of teaching, I focused on expression of ideas related to teaching assimilation to "correct" knowledge and/or ideas related to justice-oriented teaching such as facilitating student sensemaking, building on lived experiences, and explicitly addressing social, cultural, political, and historical contexts in science and students' lives. An assimilationist framework of teaching might include ideas of the teacher as communicating "correct" knowledge, a focus on the teacher's or textbook's conception of science as most important. A more justice-oriented framework of teaching might include ideas of teaching that are more student-centered, in particular with an asset-based view of students, and work to expand notions of what counts as success in the science classroom.

Data Analysis

In my data analysis I first focused on identifying and tracing my participants' frameworks of science and teaching. As the Science Story assignment and Weekly Reflection Journal were designed to serve as ways for PSTs to express and think through their ideas about science and teaching and why they thought the ways they did, I began with those artifacts. I read through each PST's Science Story editions and their Weekly Reflection Journal entries, noting any example of the PST articulating or questioning how they were thinking about science and/or teaching. I also read through memos I had written during Methods Class noting moments in class when PSTs were articulating, discussing, or questioning a particular way of thinking about science and/or teaching. I made notes about the ideas of science and teaching and how they might have been derived to refer to in the first interview with each PST.

First Interview

During the first interview, I first asked PSTs to reflect on what had supported them in articulating their ideas of science and teaching. Four of the eight participants explicitly named the Science Story as impactful for them in reflecting on their thoughts on science and teaching. In each interview, I asked PSTs about ideas of science and teaching I had noted in parts of their Science Story editions, excerpts of Weekly Reflection Journal reflections, notes from their peer teaching plans, enactments, and reflections. Four of the eight participants explicitly noted the importance of asking why and questioning assumptions about what counted as science and/or what teaching should be. Three of the eight participants did not explicitly discuss the importance of asking why, but did discuss the importance of bringing in norms and ways of knowing from multiple perspectives and/or cultures. One participant did not focus on the act of asking why, but referred to her Science Story and discussed how she questioned an experience she had and why she was the only girl in her Physics class. These interviews provided me with an idea of how PSTs were thinking about their experiences in our Methods Class, what had stood out for them and how they were thinking about some of the ideas of science and teaching that I had noted from their work.

Developing Themes for Each PST's Story

After the initial interview with each PST, I wrote out my impressions of how each PST was thinking about science and teaching across the two-semester Methods Class. I based this on the initial interview and my notes on their assignments and moments of PSTs expressing ideas or questions about science and/or teaching from Methods Class that I had previously noted. I first did this by trying to organize each PST's story around important claims or shifts in their frameworks. For example, for Felix's initial story, I identified the major shifts in ideas related to

science and/or teaching and documented what his initial idea was, how that idea shifted, and to what he attributed that shift. It was difficult to see how these different shifts related to one another when they were separated out this way. In addition, this meant that I was focused on substantial changes in his frameworks of science and teaching and would possibly be missing the claims/elements of his frameworks that remained consistent or were reinforced or became more nuanced.

After discussing this initial attempt at organizing his frameworks with Felix, I tried another method. As I was looking at framework articulation and questioning over the course of Methods Class and the Science Story editions and Weekly Reflection Journal entries were created at known points in time, I could organize PST ideas from these artifacts in three time periods. Each Science Story edition was submitted at a particular time: one near the beginning of Methods Class, one near the middle, and one at the end of the class. I organized PST ideas based on the ideas of science and teaching that PSTs articulated at these three points in time. As I was interested in PSTs' frameworks of science and teaching, I created two documents for each PST, one focused on science and one focused on teaching. I coded each PST's Science Story editions and Weekly Reflection Journal entries for ideas related to science and ideas related to teaching.

At this stage, I was coding very broadly. Anything coded "science" went into the Science document for that PST and anything coded "teaching" went into the Teaching document for that PST. Each document was organized into three sections based on when the text was submitted for class. The first section was anything from the beginning of class through submission of the first edition of the Science Story. The second section was anything after the 1st Edition of the Science Story up through submission of the second edition of the Science Story. The third section was anything after the 2nd edition of the Science Story and through the "Final" edition of the Science

Story. I read through all the ideas related to science in each section and created themes of how that PST was articulating their ideas of science across the two semesters. I did the same for teaching. For example, based on Willow's data related to science, I noted that her initial ideas of science focused on science as a tool created by humans and that scientists were seen as elite and not girls. I noted that her ideas in her second and third editions of her Science Story were similar, but she added more detail and personal connections.

Second Interview

The focus of the second interview was to member-check with PSTs regarding the descriptions I had created for each PST and their ideas of science and teaching over the course of Methods Class. I started out by sharing with each PST that I had come up with each description based on their Science Story editions, Weekly Reflection Journal entries and our previous interview conversation. I asked them to tell me what of these descriptions resonated with them, what did not fit with how they were thinking about science and teaching and their time in Methods Class, and anything else that was sparked for PSTs in terms of where some of these ideas came from and what contributed to these ideas being articulated at particular times during the class. I called attention to questions I had about what a particular idea in the Science Story or Weekly Reflection Journal entries meant or where the idea came from. For example, if an idea was written about in a Weekly Reflection Journal entry, but did not appear in the Science Story, I might ask why that idea was discussed in the journal entry, but not the Science Story. A common response was that the idea came from class discussion, not personal experience. PSTs saw the Science Story as focused on personal experiences so they might discuss ideas that were not specifically related to a personal experience in their Weekly Reflection Journal, but this would not belong in the Science Story if it did not directly relate to a personal experience. In this way,

PSTs communicated which ideas they were integrating into their frameworks of science and teaching. From their perspective, only ideas that they took up personally were added to their Science Story.

Describing PSTs' Frameworks of Science and Teaching

After the second interview, I put together an overview of main points of each PST's ideas of science and teaching with notes about what supported them in developing and articulating these ideas across Methods Class. I noticed that there was a spectrum of questioning personal frameworks that ranged from embracing critical questioning of everything to uncomfortably questioning ideas while defending initial personal ideas. Felix whole-heartedly embraced critical questioning and Alice was incredibly uncomfortable with it. Willow embraced questioning and shared her struggle with this questioning process even as she recognized its value.

To identify PSTs' frameworks of science, I focused on ideas PSTs expressed related to science as universalist or pluralist. This meant that I considered ideas that indicated how PSTs thought science was related to truth and to humans. Ideas of science as neutral truths about the world were indications of a universalist framework of science, as were ideas about science as separate from and not shaped by humans and their social, cultural, political, and historical contexts. Ideas of science as ways of understanding the world that were tied to human social, cultural, political, and historical contexts, as well as ideas of scientific knowledge as subject to question and interpretation were indications of a pluralist framework of science.

To identify PSTs' frameworks of teaching, I looked for ideas of what the teacher's role was in relation to what the teacher should do and how the teacher's role related to their goals for students. If ideas of teaching as communicating "correct" scientific information to students and/or ideas of needing to help students change their ideas to take up the "correct" scientific

ideas were expressed, this was an assimilationist framework of teaching. If ideas of teaching as facilitating student sensemaking and co-creation of meaning based in and drawing on lived experiences, explicit connections to cultural, social, political, and historical contexts were expressed, these were indicators of a justice-oriented framework of teaching.

Connecting PST Ideas to Methods Class and Teaching Practice

To identify the kinds of Methods Class activities that supported PST articulation, questioning, and revising of their frameworks of science and teaching and how those supported consideration of universalist or pluralist frameworks of science and assimilationist or justice-oriented frameworks of teaching, I matched ideas that PSTs expressed about science and teaching with the Methods Class activities that prompted expression of those ideas. By drawing from PST expressions of ideas in their Weekly Reflection Journals, whose entries were typically connected to Methods Class activities, I could identify the Methods Class activities that likely sparked the expression of those particular PST ideas. Activities fell into one or more of three categories: those designed to present the idea of science as cultural, those designed to support expansion of notions of what it meant to be a successful science student, and those designed to support PSTs in connecting sociopolitical issues with science and teaching.

FINDINGS FOR RESEARCH QUESTION1: PST FRAMEWORKS

One of our (instructors') assumptions in designing Methods Class was that PSTs need a pluralist framework of science to become justice-oriented science teachers. If a science teacher thinks that Eurocentric (or any particular set of science knowledge) scientific knowledge is neutral and universal, that teacher will have difficulty in recognizing the ways culture shapes science, which means that teacher will have difficulty supporting students to understand how culture shapes science (Le & Matias, 2019; Bang et al., 2012, Bang & Medin, 2010). Students whose culture aligns with the culture of the science being taught will likely have an easier time accepting the scientific knowledge as truth, while students whose cultures differ from the culture of science being taught will likely have a more difficult time understanding and accepting the scientific knowledge as truth without also having to change their own cultural ways of knowing and doing (Mutegi, 2011; Mensah & Jackson, 2018; Carlone & Jackson, 2007). In both cases, students are deprived of a deep understanding of science and of access to the vast majority of scientific knowledge. In the second case, students are taught that their ways of knowing and doing are less than and not scientific, which upholds white supremacy and heteropatriarchy. In contrast, if science teachers have a pluralist view/framework of science, they see science as cultural and that engagement with multiple cultural ways of knowing and doing in science strengthens the science knowledge itself and deepens students' understanding of the world and how it works. Therefore, we (instructors) designed Methods Class to support development of a framework of science as pluralistic through PSTs' articulation of their own frameworks of science, questioning of these frameworks, and discussion of their own and frameworks of science different from their own.

As we were focused on supporting PSTs in developing their philosophies and practices of science teaching, we also attended to PSTs' frameworks of teaching and how these were connected to their framework of science. In this section, I describe the frameworks of science and teaching of three of my eight participants. I also describe how each of these three focal PST's conceptions of who scientists were created a bridge between their frameworks of science and teaching.

All participating PSTs developed more detailed frameworks of science and teaching over the course of Methods Class as indicated by the ideas included in their Science Story editions, Weekly Reflection Journal entries, and interview conversations. PSTs could more clearly articulate their ideas about science and teaching, how they developed these ideas, and the values and assumptions underlying these ideas. Five PSTs began with a framework of science as universal, while three PSTs began with a framework of science as plural. Three PSTs shifted from their initial framework of science as universal to a plural framework. Two PSTs reinforced their universalist science framework. The three PSTs who began with a pluralist science framework reinforced that framework. Interestingly, all PSTs began with a more teacher-centered teaching framework of teaching as telling by the expert teacher and shifted to a more student-centered framework of teaching as facilitating student sensemaking. In Table 3, below, I highlight the framework development of three focal PSTs, one who reinforced a pluralist framework of science, one who reinforced a universalist framework of science, and one who shifted from universal to plural.

Table 3. Focal PSTs' Frameworks of Science and Teaching

PST	Science	Scientists	Teaching
Alice	**Universalist Science** Science as absolute, definitive truths People can interpret data differently, but the science itself is neutral and up of objective truths	Scientists are superior, intelligent, typically men who determine scientific truths	**Teacher-centered to Student-centered** Creating a script for students -> facilitating discussion of student ideas and teacher ideas
Willow	**Pluralist/Contextual Science** Entered class questioning prior ideas of science as made up of memorizable facts and focused on science as a tool to understand the world, this tool is not neutral + everyone can use the tool to pursue their own goals	Scientists are elite, intelligent, typically men who determine what counts as science -> anyone who does science (works to understand the universe) is a scientist	**Teacher-centered to Student-centered** Translating science for students -> supporting students in becoming part of the science community through using science practices for personal goals
Felix	**Universalist to Pluralist/Contextual Science** Science was a process that would uncover truths regardless of human bias -> science as culturally and socially shaped	Scientists are intelligent and uncover truths -> scientists do not have to be particular kind of intelligent; scientists are thinkers and questioners	**Teacher-centered to Student-centered** Communicate the best way to do Chemistry -> understand and draw from multiple epistemologies in science

Analyzing PST Frameworks

When analyzing the data for PSTs' frameworks, I focused on data related to science and data related to teaching. To identify PSTs' frameworks of science, I focused on ideas about the

relationship between science, truth, and humans. To identify PSTs' frameworks of teaching, I focused on the ways PSTs discussed the role of the teacher.

The focus on the relationship between science, truth, and humans highlighted a key component of how each PST thought about science, what science was, how science was done, and who did science. The ways PSTs expressed the relationship between science, truth, and humans provided indications of whether the PST's framework had elements of a universalist (e.g., science as a set of truths explaining the world, science as something accepted as truth) or pluralist (e.g., science as a process of working toward dynamic explanations based on evidence, science as something done and taken up by humans in particular contexts) framework of science. As Methods Class was designed to provide opportunities to explore these questions about relationships between science, truth, and humans, PSTs' ideas about science included reflections on how they were thinking about this relationship. Within this theme, PSTs indicated what they thought science was.

Part of the reason I was interested in how PSTs were thinking about science was because I was interested in how they would think about teaching science; what was their purpose/role as a science teacher? This led me to the focus on the teacher's role. PSTs expressed ideas of what a teacher should and should not do, who a teacher should and should not be, and how this was connected to the teacher's relationship with students and their science discipline. PSTs expressed ideas about what a teacher's role should be, specifically what they thought their role as a teacher should be, some of which were general to all teachers and others which were science teacher-specific. As PSTs revised their Science Story across the Methods Class, their ideas of what it meant to teach were often connected to how they were thinking about science and its relationship to truth and humans.

A useful way to think about how PSTs were connecting their ideas/frameworks of science and teaching was through examining each PST's expressions of what it meant to be a scientist and who could be a scientist. This second theme of who could be a scientist was a useful connection between ideas of science and teaching as the ways that PSTs thought about whether they or their students could be scientists were influenced by their ideas of the relationship between science, truth, and humans and influenced the role they saw themselves taking on as a teacher. A variety of factors influenced all three of these foci, including personal experiences and conceptions of who scientists were, as well as experiences within Methods Class.

In this section, I share the stories of three PSTs to illustrate the variety and similarities in PST frameworks in each theme and how their ideas in the three themes come together to create a picture of each PST's framework of science teaching. In the Findings section for research question 2, I provide examples of Methods Class opportunities to learn which supported the articulation of and reflection on these frameworks of science teaching.

Finding A: PSTs' Frameworks of Science

In this section, I draw on the experiences and ideas of three focal PSTs to illustrate the variety of ways of thinking about science, truth, and humans that existed in our Methods Class and the life experiences and social structures that supported the development, questioning, and articulation of these ideas.

The ways PSTs thought about the relationships between science, truth, and humans was a key part of their framework of science as it connected to how they thought about themselves in science, as well as their role as a science teacher. These three constructs appeared in all participants' data related to their framework of science. In coding this data, the ways participants saw science as related to truth emerged in various forms in which participants described science

as a static body of facts taken as truths, a process of examining and explaining phenomena, a combination of the two, or something in between. The relationship between science and humans was related to truth as participants brought up the connection between science and humans in terms of who could do science or was considered to be a scientist (this led to the second theme of science identities) and in terms of science as neutral and objective (and seen as made up of truths) or science as something done by humans and therefore changeable, fallible, grounded in human perspectives, cultures, and social contexts. This focus on the relationships between science, truth, and humans was also a primary theme of our Methods Class as we (instructors) shared the goal of supporting PSTs in exploring the cultural and social contexts of science, which necessitated an examination of what science was, how it was created/used, and by whom. These ideas about the relationship between science, truth, and humans fell on a spectrum of ideas/thoughts ranging from science as objective truth (i.e., science as absolute truths that represent or are synonymous with reality, which are communicated by particular humans, called scientists, but are not influenced by those humans/are apart from those humans) to science as relative and contextual (i.e., questioning what truth is as science was created by and for humans as a means of understanding and acting in the world therefore science is contextual and different depending on who does the science, in what contexts and for what purposes). Some PSTs reinforced their frameworks of science and their ideas of the relationship between science, truth, and humans, while others adjusted their frameworks across Methods Class.

I describe how three focal PSTs articulated their frameworks of science, in particular their ideas of the relationship between science, truth, and humans. Examining how each PST thought about the relationship between science, truth, and humans provided insight into what exactly each PST thought science was, what they thought the purpose of science was, how they

thought science was done, and who did science. By answering the question of how science was related to truth, I gained an understanding of whether the PST thought that science was a static set of truths about the world, a process to determine static truths, a process to work toward understanding the world, a set of truths based on evidence that could change based on new evidence or interpretations of current evidence, as some examples. Through this process, I gained a greater degree of detail than if I simply asked PSTs what science was and was told that was asking questions, positing a hypothesis, testing that hypothesis, and answering the question based on evidence from that test. This description of the scientific method is not inaccurate and is part of how each PST thought about science, but it is lacking basic ideas about what science is, how it is done, and by whom, all of which were important for thinking about science as something done by humans, shaped by culture, and best served by being critically questioned by those engaging in science practices and taking up scientific knowledge.

Alice - Consistency in Framework (Universal)

Science as Truth. For Alice, science and scientific truths are synonymous with reality. Regardless of how scientific truths are determined, once they are codified, the canonical truths describe how the world works. The way the world actually is does not change depending on who does the science or communicates the way the world is. As Alice explained in an interview after Methods Class had ended, “the English story will change based on perspective, and like, I think a science story. Like, I think it should be the same regardless of who wrote it, and what their beliefs are and where they came from, and if I do the same experiment as this guy, then we … get the same results.” (Alice, personal communication, July 20, 2021). For Alice, science was objective and the process of science should eliminate any influence from different people who might happen to be doing the science. Alice also focused on science as a final product (i.e.,

scientific knowledge) rather than the processes that produced that product. If the processes were done accurately, the scientific knowledge produced would be a truth. This scientific knowledge is an objective, accurate representation/recreation/explanation of the world as it is. According to Alice, people may explore multiple ideas, but there is always one correct truth of how the world actually is and works, this is scientific truth and often also called science. This was the way Alice expressed her ideas of science throughout Methods class and was how she described her view of science in her interviews the summer after Methods Class. “If I am thinking about science being truth versus perception. I'm going to go heavily that it should be truth and less perception, like perception by students, perception by the teacher, like I just don't- I think that people can put their own experiences into scenarios, while still applying truth.” (Alice, personal communication, July 20, 2021). Here, Alice mentioned that people have experiences and that those can be drawn on, but that they do not change what is truth.

In this section, I draw from Alice’s Science Story editions, Weekly Reflection Journal entries, and interviews after Methods Class had ended to illustrate how Alice articulated her ideas of science as objective, neutral truths and how she grappled with the ideas of humans’ role in science.

Particular People Determine Scientific Truths. One of the ways Alice enacted her frameworks of science as objective truth was by determining where such objective truths could be found and accepting the knowledge from these sources as unequivocally true. Alice accepted textbooks, course instructors, and professional scientists as expert sources of scientific truths (i.e., representations and explanations of reality). Alice trusted sources of information/knowledge that she viewed as objective or expert. Alice explained which sources of information she trusted in the following weekly reflection journal entry:

> I'm a pretty skeptical person, so outside of class (since I trust instructors), I question most information that I haven't heard about before. I don't like to go to one source and take everything it claims as factual because I think it often takes multiple sources to build an accurate picture of how something works or why something happens in the way it does. I trust textbooks, because they share information from experts, and a teacher typically recommends/mandates readings from a textbook. (Alice, weekly reflection journal, December 3, 2020).

Alice trusted information from experts or expert sources, such as course instructors and textbooks. When Alice was asked which evidence, interpretations, or explanations she trusted as a scientist, she responded:

> As a scientist, I am typically more interested in raw data than I am of another person's interpretation of that data. I definitely trust professionals for advice or interpretation of research over myself, but I like to be able to draw my own conclusions from data rather than someone explaining their conclusion or understanding of research without data to back it up. When looking into something for my own research or regarding a topic I need to teach students, I look to professional scientists for answers. I accept and value their research and expertise over someone who is less educated in the topic. (Alice, weekly reflection journal, December 3, 2020).

Alice expressed a hierarchy of knowledge that she would trust with a professional scientist's interpretation of data at the top and someone's explanation without supporting data at the bottom. She placed her own interpretation of "raw data" below a professional scientist's interpretation, but above others' explanations or conclusions based on that data. In this reflection, Alice gave more weight to the interpretations of professional scientists than those of anyone else. Alice also ranked "raw data" above someone else's interpretation of data. Alice believed that there was such a thing as "raw data" which meant she did not consider how that data was generated, by whom, or for what purpose. "Raw data" was neutral and objective and close to reality.

Alice hinted at a difference she saw between professional scientists and students in the same Weekly Reflection Journal entry when prompted by a question about what evidence/interpretation/explanations she valued and expected as a teacher:

> As a teacher, I expect students to draw from their own lives to explain things. I naturally do this when trying to explain something, and I think most other people do this as well. I try to accept and value evidence/interpretations/explanations that are different from my own, especially coming from students, because I don't want to squash their thinking or make them think their ideas/experiences are less valid than anyone else's. I do, however, have trouble with the concept of subjective truth, especially in science. I think it is possible to accept and value all initial ideas about a phenomenon, but that students need to learn scientific truth to back up their claims. (Alice, weekly reflection journal, December 3, 2020).

In this journal entry, Alice expressed both that she valued student thinking, but that she assumed that this student thinking would be different from scientific truth and that students would not back up their claims with scientific truth. Student ideas are valuable for students to think through, but they are not scientific truth. By excluding students and teachers (including herself) from the process of science knowledge generation, students and teachers were prevented from being/acting as scientists, according to Alice's framework of science.

Importance of Shared Definitions and Definitive Answers. An affordance of Alice's framework of science as objective, neutral truth was that it was simple to decide what to believe and what to question or doubt. Science gave exact answers to questions and there was no need to spend time and energy debating something that was simply truth. In an uncertain world, definitive truths can be comforting, as Alice expressed in her second edition of her Science Story, "She loves that science gives her definite answers to questions. [Alice] never enjoyed the open-endedness of other classes where many different answers seemed to be 'right' So, she clung to science and math as they always seemed to have an exact answer she had to find She

found that some of these exact answers she came to love got blurrier as she went through life" (Alice, Science Story 2, December 7, 2020). While Alice added this idea of "exact answers" getting "blurrier" she ultimately deleted this section from her third edition of her Science Story. When I asked Alice about this deletion in our interview the summer after Methods Class, she said she thought the story was too long, so she cut some things and while she still believed this, it did not need to be in her Science Story.

A constraint of this framework of science was that it limited understanding of the scientific knowledge itself by limiting what can be questioned, stopping Alice from considering how context may have shaped how people explore and explain reality. This was evident as we continued to talk and Alice shared more about her claims of science being neutral and objective. In our interview, she shared that she relied on textbook definitions, even, or especially when confronted with multiple definitions of a concept:

> I don't want to be disrespectful of people's culture and their whole belief growing up, but like in that instance I'd be like, "What does our book say in the glossary?" …. And yes, I get that that can get all into the like, "Well, someone wrote that book and it was some white guy wrote it so now we have a whole different-" you know what I mean. But I kind of just go with them. (Alice, personal communication, July 20, 2021).

This is another instance of Alice's conflict between valuing people's ideas and experiences and believing that scientific truths of textbook information would supersede or invalidate those ideas and experiences. Alice articulated that she did not want to tell someone that their cultural beliefs were wrong, but that she would choose to follow the textbook ideas and definitions, which were probably written by a white man, but she would disregard this and enforce reliance on the textbook content and definitions. While that definition may have been written by a particular person with particular beliefs and perspectives, for Alice, this did not change the content or definition itself. This knowledge/information was neutral and objective. Students with particular

cultural beliefs could bring erroneous ideas and definitions to science class, but textbooks written by people of other cultural beliefs were above reproach and question. For Alice, the content of textbooks was not connected to the authors of those textbooks. The content itself was neutral and objective because it was in a textbook.

Alice explained her reasoning behind utilizing textbook definitions and making sure everyone used the same definition. Correct definitions were important to Alice because language was important, had meaning, and working with different definitions in a group of people led to misunderstandings at best and harm at worst. Alice explained this in her weekly reflection journal and Interview 1 when she discussed a day in Methods Class when the idea of trauma-informed pedagogy had come up. She shared how allowing just any definition of the word "trauma", specifically a posited definition in class of trauma as anything that changes your worldview, was harmful and devalued/diminished the experiences of people who have actually dealt with trauma:

> So, in class, the word trauma was used. And someone said that trauma is anything that changes your perception of the world. And I went on a text rant to my friend because like, that's not the definition of trauma, and I think it devalues people's trauma of the definition of a deeply distressing or disturbing experience. I think it devalues people that have had distressing or disturbing experiences, by saying trauma is anything that changes your worldview, or…makes you question perspective on something…. So that's what I mean when I say like, we need to be using definitions how they are defined. (Alice, personal communication, July 20, 2021).

Definitions were important for clarity and to prevent harm. It was not important to Alice to question where a definition came from or its context, only for everyone to use the same "accepted"/sanctioned definition. Alice's assumption/claim was that there needed to be one definition and that this definition needed to come from outside the classroom community, and

that the definition in the textbook was superior to or worked just as well as any other definition, so why not choose the textbook definition that already exists.

Knowledge from sources such as textbooks, course instructors, and professional scientists did not need to be questioned because, by definition, for Alice, knowledge from these sources was truth. In addition, having a shared understanding of this knowledge was beneficial for people because this way everyone would start from a common way of thinking about any topic.

Science as Separate from Humans. Previously, we (instructors) had asked PSTs to read four examples of science with underlying frameworks made visible/semi-explicit and reflect on what the framework was in each example and how it mattered to the science. One example was of the common explanation of fertilization as a process driven by sperm with the egg as a passive observer being tied to patriarchal views of male and female human roles preventing these scientists in this context from asking questions about the egg's role in fertilization, thus shaping the scientific explanation of fertilization which focused on the active role of sperm. In her Weekly Reflection Journal, Alice wrote, "Framed in a less male-centered way; gives fertilization some credit to females. This matters because it presents a new model for fertilization and places value on female roles." (February 1, 2021). This seemed to indicate that Alice noticed that different perspectives of scientists could result in different scientific questions and explanations. However, later, during our interview after Methods Class, Alice shared her frustrations with the fertilization explanation and her doubts that any sort of sexist thinking had any bearing on the explanation of fertilization, "I'm looking at this fertilization egg thing. Like, you can frame it to be less male-centered but what's happening with the fertilization is the same regardless how you frame." (Alice, personal communication, July 20, 2021). Alice did not see evidence that the people investigating the process of fertilization had internalized sexist views and, even if these

people did hold these views, this would not affect the science. Alice reflected on an example of an Indigenous scientist who refused to sedate and draw blood from buffalo because this went against her beliefs of buffalo as relatives and autonomous beings to be treated with respect. Instead, this scientist pursued a novel method of collecting DNA from buffalos by isolating it from their feces. Alice thought that this was a valid example of people's different perspectives influencing the way they did science, but that while this might affect the process of science, it would not affect the product:

> Like the buffalo poop one. I think that's a valid- like there's a reframing there, but the science itself is what it is. And, like, the results that you get from…gathering DNA samples, those are the results you get. And if you do it in a different way, you're getting the same results. That's what the truth is. If we're like, thinking about what's the truth, versus… the framing of it. So I think, like, almost, like, you could have different framing of science things, but they should point to the same story or process, or whatever it is in the same way. (Alice, personal communication, July 20, 2021)

Alice asserted that science gets at truth. There may be multiple ways of approaching science to get at the truth, but ultimately, there is one truth and that truth should be the result of scientific inquiry. When pressed on how we know if we are getting the full story or the truth, Alice drew from her claim that experts were the ones who knew what was truth. "We don't know if we're getting the full story with it as it is here, I guess I don't know like, unless I get my medical degree in embryology," (Alice, personal communication, July 20, 2021). Determining whether knowledge is complete and factual was best done by people with an advanced degree in the subject. Alice had great confidence in an archetype of experts who were often conferred their expert status by an advanced degree and/or their profession/title.

Alice's idea was that while people might have biases or different perspectives or framings, the purpose of science was to describe and explain reality, so individuals' biases and

perspectives would not affect the end product in science. Alice articulated and strengthened her claim of scientific knowledge as neutral and objective, even if the people doing science were not neutral or objective.

Willow - Consistency in Framework (Plural, Contextual)

In her Science Story, Willow traced her ideas of science from her early childhood up to and including her current ideas of science. Across her Science Story editions, Willow added more details and analysis of the experiences that supported her development of her particular ideas of science. Willow utilized her Science Story to articulate ideas of science that she developed based on multiple messages and experiences in and out of school with which she no longer agreed. Willow shared that her initial idea of science was that it was made up of given information to be memorized, but that she had rejected that idea and currently thought of science as a tool to be adapted and used by humans. In her initial idea, Willow wrote about science as something already established and not to be questioned, similar to an idea of science as made up of truths. Across her Science Story editions, Willow provided examples and detailed analysis of how those experiences supported her development of this idea of science as a set of established facts/truths. In her writing, she also clearly communicated that she no longer saw science in this way, but instead focused on science as a tool created and used by humans. Finally, in her interview after Methods Class, Willow expressed how her idea of science as an adaptable tool rather than as a producer or body of truths was not only a practical way to think about science, but also a more justice-oriented way. Willow reinforced her framework of science as an adaptable tool with her claim that there was not one correct way to explain the world and that treating one cultural way of explaining the world as the only correct way resulted in oppressing other cultural ways of explaining the world.

Rejecting Science as Established Truth. Willow shared in an interview during the summer after Methods Class, that one of the things she was thinking about was the relationship between science and truth. The conclusion she had come to was that she would never know enough to definitively say an idea in science was right or wrong, but that determining if an idea was right or wrong was not particularly useful in science anyway:

> Something I keep coming back to, more recently, is that I'm never going to have enough information to know what's true or if there is "true". It's just not humanly possible to ever have…adequate information. So, I think the best thing I can do is just treat information, and the way we use information, with kindness. Not say that people's ideas are wrong, or say that only one idea is right…and presenting science in a way that is open-minded to our students' beliefs too…. I think that if science is presented as "these are the facts and they can't be challenged." It doesn't really lead to a ton of innovation or new discoveries or evaluating old information. (Willow, personal communication, July 26, 2021).

Willow added that not only would focusing on science as truth or what was right or wrong not lead to innovation or discoveries, but doing so discriminated against people:

> I think it discriminates against certain types of belief systems and especially groups of people who weren't as involved in creating the body of science that is commonly taught in schools. Like if you're not a straight white man, your ideas aren't really represented…. So, I wouldn't want to present that what I am teaching is the only right way because then that means these other groups of people and their ideas didn't matter and they aren't the right way of looking at the world. (Willow, personal communication, July 26, 2021).

Willow rejected the idea of science as uncovering or generating or determining truths because she, and no one else, could ever know enough to be certain that any information was definitive truth, but also because a focus on finding truths was not useful and would be harmful to people. Instead, Willow focused on engaging with ideas, challenging facts, and exploring new ideas. In her Science Story, Willow focused on science as a tool that all students should have access to and could use in ways that were relevant to their lives while also analyzing her previous ideas of science as an established set of facts to memorize.

Analyzing Development of her Previous Framework of Science. In her first edition of her Science Story, Willow explained that she previously saw science as already established information to be memorized. She had learned that by memorizing information presented by teachers and then demonstrating this memorization upon request, she was treated/labeled as smart and successful in multiple areas of her life, including her science classes. She connected this to other pursuits, such as her love of Pokémon and her music training.

As Willow continued in Methods Class and revised her Science Story, she added more details about her personal experiences and how these contributed to her ideas of what science was. She included analysis of how her love of Pokémon supported her success in science classes, especially Biology, as both valued skills of looking up, taking in, and memorizing information about multiple organisms in a system with a set of guiding rules connecting structure and function:

> I feel like I can't talk about my childhood without talking about Pokémon because it was such a huge part of my life…. I have a ridiculous amount of information about Pokémon memorized.… I think growing up as the resident Pokémon expert taught me 3 things. 1, I had the capacity to memorize a large amount of information very well with relatively little effort. This has been super helpful in school, especially in classes where I was graded based on my ability to regurgitate facts. 2, I loved being the expert. I liked when people asked questions and I liked giving them the answers that were useful for them. It made me feel useful…. 3, I learned how to gather information. If I didn't already know the answer, I used books and later the internet to figure out what I wanted to know. This is also an important skill to have as a scientist. (Willow, Science Story 2, December 7, 2020)

Willow also included connections between her study as a classical musician and her success in school science as both music and school science required taking up a system of classification and organization and reproducing this correctly through performance. Willow questioned that this

was all there was to music or science, but expressed that this was how both were presented to her. Willow shared how she felt her music training and her science schooling were related:

> I feel like another thing I need to mention is that music has always been a huge part of my life…. Classical music is pretty rigid, and this is also the way I viewed science until I came to college…. I was taught that it was my job to play the piece exactly as the composer had written it. I viewed science as something that was static and rigid as well for most of my life. I thought that my job as a scientist was to memorize as much information as possible and collect information to solve problems. I didn't see much room for my own opinions or feelings in science. I think that in both music and science, I viewed my role as being a faithful mouthpiece for something that was already established, whether it was playing classical music or acing tests. (Willow, Science Story 2, December 7, 2020)

Willow stated this as a belief she had growing up and how this idea was reinforced through her experiences in school. There was already a system of information in place/established and it was her job to memorize and faithfully reproduce this system. Even as Willow explained these experiences and how they shaped her ideas of science and what it meant to be successful in (school) science, she pushed back on and questioned whether this was everyone's experience, the intended experience, or an accurate representation of music or science.

As Willow expressed in her Science Story editions, science was presented as an established set of facts to be memorized and she accepted this presentation of science as she was successful in taking up science this way and rewarded by peers and teachers for doing so. Still, Willow had already begun to question this conception of science and to consider that science was not simply an already established set of information, but a process real people engaged in to explore/investigate/learn more about the world. Science was a tool to be used to learn more about the world and to make informed decisions.

Science as an Adaptable Tool. Willow started Methods Class with the idea that science was "a man-made tool for understanding the world around us. Science isn't perfect, and it isn't

above human bias like I previously thought. If anything, racism, sexism, and some of the worst part[s] of humanity have been ingrained in science throughout history," (Willow, Science Story 1, September 21, 2020). Willow saw science as a tool, created and utilized by people, and subject to the biases of people. Science was a useful tool for understanding the world and it was important to understand the limitations of science and how humans shaped science. Willow stated this initial idea of what science was in her first edition of her Science Story. She added explanations as to how and why she developed this idea in her later Science Story editions.

Willow drew from her idea of science as something that people do, rather than just a set of information for people to take up in her response to a prompt asking how her experiences with professional science and classroom science aligned or not:

> I think that it is important for students to build background knowledge about science, but it's also important to practice scientific techniques…. I want to show students what professional scientists do. I think it would be beneficial for students to learn about how scientists apply these ideas to solve problems in settings such as research. (Willow, Weekly Reflection Journal, September 24, 2020)

Willow recognized that there was information generated and used by scientists that students could learn, which was important, but while this was what she had primarily learned in science classes, it was not sufficient. Willow wrote that "practic[ing] scientific techniques", seeing "what professional scientists do", and learning "how scientists apply these ideas to solve problems" was important for learning science. Science was something that was done and applied for a purpose, not just information to memorize.

Willow articulated her idea of science as being accessible to people and why this mattered to her in more detail in the second edition of her Science Story:

> Science is a tool for analyzing the world around us. Science teaching is to teach students how to use this tool for their own benefit. I think these ideas come from my experiences in science (and the rest of my life – they're so connected they're inseparable to me). I have often felt excluded from

> science. I felt like I was running a race and the finish line of becoming a scientist was constantly moving farther away. I want my students to feel like science is accessible to them, as I think it should be. I think the way that I accomplish this is by positioning science as a tool that is adaptable for whatever you are interested in, rather than a collection of knowledge that is gatekept by old white dudes with PhDs. I don't think this view changed very much over the semester. Rather, our class discussions helped me solidify and better articulate these feelings. (Willow, Science Story 2, December 7, 2020)

Willow did not disregard science and its utility due to biased influences of people, but instead focused on the importance of this useful tool being accessible to and adaptable by everyone, not just "old white men with PhDs" (Willow, Science Story 2, December 7, 2020). Part of the problem with bias and ingraining racism and sexism was aligned with only a small subset of people with particular shared views having access to and shaping science.

For Willow, science was not "truth" but "a tool for analyzing the world…" (Willow, Science Story 2, December 7, 2020). Science could not be separated from humans. It was something done and used by humans for their own particular purposes. Science helped humans understand and analyze the world around us. Like any tool, science could be used in multiple ways depending on the person/people wielding it. Generally, it was a useful tool that should be accessible to everyone, not relegated to use by a select few who determined what and how knowledge should be generated.

Recognizing Limitations and Framings/Frameworks of Science. Willow drew on ideas of framings/frameworks and cultures to explain in more detail the relationships she saw between science, truth, and humans. Willow saw science as a useful tool with limitations and that understanding those limitations both supported more useful science processes and outcomes and reduced oppressive actions/practices in science and science education.

Willow provided more detail on how she was thinking about science as a tool and the limitations of this tool in her response to a prompt asking what ideas about science and science

teaching were raised for her by some scenarios discussed in class by restating her idea of what science was, “I think science is just a tool to explain the world around us,” She continued on to state a limitation of the tool of science and an example she encountered in high school, “However, I think that science is generally better at answering “how” questions than “why” questions. My AP biology teacher would always say that the purpose of life is to reproduce (at least from a biological perspective). I think I would have to disagree, at least to this being the only acceptable answer. I don’t think questions like this can be answered using only canonical science.” (Willow, Weekly Reflection Journal, November 2, 2020). In this journal entry, Willow used the prompt about scenarios discussed in class to reflect on her own experience in a classroom in which a teacher expressed a framework of science that differed from her own. Willow shared that this example illustrated a limitation of science. Science could not explain everything definitively. As Willow saw it, science was better at answering “how” questions, but often the “why” questions required a person to draw on other ways of thinking about the world. Willow recognized her AP Biology teacher’s statement that “the purpose of life is to reproduce” as one particular way of thinking about the world, but not the only way and certainly not a way that should be treated as definitive truth.

Willow continued reflecting on ideas of multiple perspectives in science in her Weekly Reflection Journal entries in the Spring Semester of Methods Class. In response to a prompt asking why it might be important that scientists recognize their own framings/frameworks of the world, Willow responded:

> It’s essential to recognize your framing because it will have an effect on what you think is important and what you think is less important. It’s important to figure out what these things are. That way, you can see your perspective as a framing rather than a definitive way of experiencing the world. It’s important to realize that there are things you aren’t focusing on

> that are still important, because so many things in science are interconnected. (Willow, Weekly Reflection Journal, February 18, 2021)

Willow explained here that framings/frameworks affect what a person sees as important and that it is important to recognize that this is one way of perceiving the world. Based on the idea of framings/frameworks, Willow supported her idea that science did not provide definitive truth because the people doing science did not all share one definitive way of experiencing the world. She also included the idea that understanding one's own framing/framework was important in science because so many things are interconnected so a scientist's perspective on the world could be connected to the science that they were doing. What the scientist deemed important based on their perspective/framing/framework could impact how they used the tool of science to explore and explain the world. Willow explained further that recognizing different perspectives and values made for a better learning environment and for better science:

> I think it's important to recognize that your own framing is relative, and not the only right way to view the world. The things that other people value are also valuable and important. We should make sure to leave space for these viewpoints and respect them. This creates a more inclusive learning environment, as well as creates a more robust understanding of the universe, which is arguably a major goal of science. (Willow, Weekly Reflection Journal, February 18, 2021)

In this journal entry, Willow connected the idea of people having different perspectives or frameworks to the way science was done. She stated that there was not one definitive way to experience the world or to do science. She also asserted that recognizing these multiple ways of experiencing the world as influencing science would result in "a more robust understanding of the universe". Willow explained here that recognizing and interacting with multiple perspectives was a strength in science. Not ascribing to one definitive way of experiencing and explaining the world was not a problem, but an asset in science.

Summary. In her Science Story, Willow focused on science as a tool that all students should have access to and could use in ways that were relevant to their lives while also analyzing her previous ideas of science as an established set of facts to memorize. Willow identified her previous ideas of science as tied to definitive truths about the world, analyzed the experiences that had supported her development of these ideas, and expressed the different ideas of science that she now held. Willow had already rejected her initial ideas of science as tied to truth in the form of established facts to be memorized and had formed a different idea of science as a tool for humans to explore and explain how the world worked. Across Methods Class, Willow worked to articulate her current idea of science more clearly, examine and explain why she had thought of science as a set of facts previously and why she had expanded this idea to focus more on the idea of science as a tool. She also used Methods Class opportunities for reflection and articulating ideas, such as her Science Story and Weekly Reflection Journal, to elaborate on her ideas of science and what she saw as supporting these ideas.

Felix - Shift in Framework (Universal to Plural/Contextual)

From Science as Truth to Science as Culturally Grounded. While Felix described science as both information and a process across the entire Methods Class, the way he described how he thought about the relationship between science and truth shifted over time. Felix initially described science as "a collection of information passed down through human generations" that is made up of truths uncovered over time through a "logical process that looks at evidence to base an argument off of." (Felix, Science Story 1, September 21, 2020). About halfway through our Methods Class, Felix had added that "Science is informed by and created by society and culture scientists construct their own reality when interacting with data," and "Science is not authoritative, it is collaborative." (Felix, Science Story 2, December 7, 2020). Finally, at the end

of our Methods Class, Felix explicitly stated that, “Although science is often portrayed as fundamental truth…it is far from it,” and “Within the scientific community of the US, an epistemology is often reproduced as we talk about and interact with information deemed scientific. People in this community often view scientific knowledge as truth, an absolute truth of the universe without acknowledging the intimate roll humans have in the formations of such ‘truths.’” (Felix, Science Story 3, April 20, 2021) Felix shifted from identifying science as uncovering truths in his first edition of his Science Story to stating that this idea of scientific knowledge as truth as being attributed to a common way to think about science, but that ignores the important role of humans and their cultural context in shaping scientific knowledge. Delving into Felix’s Weekly Reflection Journal entries provided some context for these shifts in his conception of science.

Felix’s Shifts Across Methods Class. Felix reflected on the relationship between humans and science in response to a Weekly Reflection Journal prompt asking how he thought his ideas of what is natural connected to his views of what counted as science. Felix did not have specific ideas about how his views on what was natural related to his views of what counted as science, but instead shared his idea that “Everybody can have different interpretations of words, phrases, questions, answers, books, art, movies, science. We all have individual experiences which shape how we interact with the world and interpret speech or actions. This only further provides evidence that we all have different knowledge, due to our individuality,” (Felix, Weekly Reflection Journal, November 2, 2020). Felix drew from his idea/claim that different people with different experiences would interact with the world in particular ways and create knowledge for themselves in ways that were unique to them. This meant that people would also differently interpret science specifically and the world more broadly. Here, Felix shared an idea that would

support his claim that there was not a set of definitive scientific truths, but rather science was shaped by humans and their social and cultural contexts.

In this same journal entry in response to the part of the prompt that asked what ideas about science and science teaching were raised by the scenarios in class, Felix wrote that, "Science is made of questions, observations, hypotheses, and curiosity and science teaching involves the facilitation of science." (Felix, Weekly Reflection Journal, November 2, 2020). Felix named things science was made of and included things that were not inherently about truth, but about questioning and seeking to understand. Felix went on to state, "The scenarios did raise questions about how science is represented and the framing of knowledge within science. I believe science should not be authoritative but collaborative, within a classroom, teachers can hold significant power…. Great care must be taken with that knowledge. (Felix, Weekly Reflection Journal, November 2, 2020). Felix noted that he had questions about how science was represented and how knowledge was framed, indicating that the ways science was represented and framed mattered. He followed this with a statement that science should be collaborative, referring to the idea that what counted as science and how science knowledge was generated and engaged with should be a collaborative endeavor, not something dictated by one person/authority to others. This fit with the theme of the scenarios, which each presented a different situation in which students and teachers brought different framings/frameworks of science to the classroom and the teacher either recognized and valued these multiple frameworks or the frameworks were left implicit and the students' knowledge was treated as incorrect. In this journal entry, Felix wrote that he had questions about how science was represented, that science should be collaborative, and that those in positions of power should be careful with how they exerted that power, indicating that he was starting to think about the implications of how science was

presented in classrooms and that one way of thinking about science should not be portrayed as the only way. This was a move away from Felix's initial idea in his Science Story that science was made up of truths that would eventually be figured out through the scientific process and toward an idea of multiple ways of doing science and explaining the world.

Toward the end of the Fall Semester of Methods Class, Felix connected historical, social, and cultural contexts to the ways people understand and use science and scientific knowledge. In response to a Weekly Reflection Journal prompt about which evidence/interpretations/explanations he expected, accepted, and valued, Felix wrote that as a teacher, he often drew from historical evidence, but that this evidence was drawn from "western culture" and therefore would not provide a complete picture of scientific knowledge, how it was developed, and what people understand about the world. In addition, Felix identified that drawing on this narrow slice of scientific knowledge could also "sustain historical injustices around who can 'do' science," (Felix, Weekly Reflection Journal, December 3, 2020). In contrast, when writing about the evidence and explanations he accepted and valued as a scientist, Felix wrote that he would "Question everything, demand evidence, seek explanations, challenge the status quo, seek other perspectives. Without these ideas, science does not occur, and knowledge is not generated," (Felix, Weekly Reflection Journal, December 3, 2020). When he thought about science, Felix focused on the practice of questioning, challenging current explanations and ways of doing things, and seeking other perspectives as essential for doing science and generating knowledge. Here, Felix described science as an active process involving constant questioning and generation of knowledge. Science was not made up of particular accepted truths, but rather was a process of questioning accepted knowledge to consider other

perspectives and explanations and strive for deeper understanding of the world. For Felix, scientific knowledge was not settled, but dynamic.

At this point, about halfway through Methods Class, Felix had moved away from an idea of science as a process that would produce truths in spite of human biases and toward an idea of science as connected to human contexts and individual experiences, as well as a continual process of questioning and seeking multiple perspectives to continuously generate knowledge. Over the course of the second half of Methods Class, Felix took up more specific ideas of the ways culture and identity were related to science and the generation of scientific knowledge.

In the Spring Semester, we (instructors) explicitly introduced the idea of framings/frameworks and how these might be connected to science and scientific knowledge. Felix took up this idea of framings/frameworks immediately, as evidenced in his Weekly Reflection Journal entries. In one entry, we (instructors) asked PSTs to read four scenarios, each of which provided an example of science shaped by a particular framing/framework. PSTs were asked to reflect on the framing/framework used in each scenario and why that mattered to the science. Felix wrote about the scenario explaining a common way of explaining fertilization and how this explanation aligned with stereotypical gender roles that, "Stereotypical gender roles, which are ingrained in our culture, therefore are ingrained in the cultures of the people who historically participate in science, perpetuating gender roles." (Felix, Weekly Reflection Journal, February 1, 2021). Here, Felix explicitly connected humans' cultures and framings/frameworks to the science that was done and that the science reflected these cultures and related framings/frameworks. Felix went on to write, "Science is a social enterprise, those values held by the 'people' doing science are ingrained in that 'science.'" (Felix, Weekly Reflection Journal, February 1, 2021). Felix stated clearly that science was social and that science was not objective

truth, but reflected and was shaped by the values of the people doing science. Felix explicitly distanced science from truth and stated a direct connection between the people doing the science and the form and content of the science itself.

Felix connected framings/frameworks and human social context with science even more explicitly in his Weekly Reflection Journal entry focused on how framings/frameworks were related to science. Felix called into question the idea of science as neutral, writing, “Despite the appearance of scientific neutrality, all knowledge is held in a certain set of values and beliefs, as knowledge is built in a context, affected by culture and society; therefore, the knowledge building process of science is a social enterprise, affected by the beliefs and values of those who create such knowledge.” (Felix, Weekly Reflection Journal, February 5, 2021). At this point, Felix clearly positioned science as something done by humans in their particular social and cultural contexts. Science was not only done by people who were shaped by their particular contexts, but the science itself was shaped by those contexts and the beliefs and values of the people doing the science. Felix had shifted away from his idea of science as uncovering truths and toward an idea of science as grounded in social and cultural contexts.

Felix wrote about the importance of scientists recognizing their own framings/frameworks of science so that the scientific community could act in the interests of the broader community, stating, “If scientists recognize that people hold different values and beliefs outside the scientific community, decisions often made by the scientific community made for the ‘greater good’ would accurately represent the commonalities in other communities outside science.” (Felix, Weekly Reflection Journal, February 18, 2021). Felix explained that it was important for scientists to recognize multiple ways of thinking about the world and he placed those ways of thinking as outside of the scientific community. It seems that it was not that Felix

thought that these multiple ways of thinking did not belong in the scientific community, but rather that he did not think those ways of thinking were currently represented in the scientific community. Later in the same journal entry, Felix wrote, "Without acknowledging people have a different concept of reality, people will continue to be ignorant of those differences in looking at the world. Being blind to other perspectives we may become convinced that we are 'correct' and our way of knowing is the truth. Passionate advocacy of ways of knowing without considering the other opinions would produce science which dominates other ways of thinking." (Felix, Weekly Reflection Journal, February 18, 2021). Felix saw the scientific community as made up of people who shared a particular social, cultural, and historical background and therefore, shared a similar framing/framework of science and the world. It was important for these people/scientists to recognize that theirs was not the only way of viewing the world so they did not come to the erroneous conclusion that only their way of knowing was correct. Felix noted here that no one way of knowing represented the truth, but rather, there were multiple ways of thinking that should be recognized and included in science.

By the end of the Spring Semester of Methods Class, Felix had moved beyond discussions of science as truth or not and to an exploration of the historical, cultural, and social contexts of what he had known only as "science". Felix shared that he wanted to focus on understanding the relationship between "western culture" and science:

> Western culture and science. I want to address the relationship between them and how science is very much defined by western culture, due to the origins of what people call 'science' and the dominant culture that exists in science, meaning the majority of people who created what people in general think of as science was dominated by white men from western societies. (Felix, Weekly Reflection Journal, April 8, 2021)

Felix had identified a particular relationship between what he referred to as "western culture" and science. He expressed a desire to use his Science Story as a place to explore the ways what

has been referred to as “science” had been primarily grounded in the knowledge and practices of a group of people from this particular shared culture. Felix had identified that what he had thought of as “science” was not neutral and representative of all science, but was specific to a particular culture.

Across the 3 Focal PSTs

One important claim within PSTs’ frameworks of science was about the relationship between the experiences and perspectives of the people doing science and the science itself. Alice’s framework relied on a claim that the science itself would not change regardless of who was doing the science. According to Alice, science was directly tied to an objective reality, so regardless of who did science, or worked to name/describe/explain that reality, the reality, and therefore the science, would not change. Willow and Felix expressed different claims about the relationship between people’s experiences and science. Both Willow and Felix drew from claims that people’s individual experiences shaped the ways they would do and interpret science. These individual differences/experiences shaped how scientific knowledge was generated, interpreted, and applied. Individual experiences shaped the science itself in different ways.

Each PST’s claim about the relationship between science, truth, and humans also supported that PST’s idea of the relationship between science and truth as well. For Alice, because science represented objective reality and was not influenced by the humans doing the science, science was made up of truths about the world. Alice did not think that she could know with certainty if particular scientific knowledge was the whole story and therefore definitive truth, but she trusted that professional scientists had done this for her in their area of expertise. For Willow and Felix, science and truth had a blurrier connection. For Willow, science was a tool to analyze and understand the world. Different people could analyze and understand the

world in different ways. The goal was not to get to some definitive truth, but to strive for deeper understanding of the world while knowing that no one will ever know everything, therefore no one will ever know for certain that any knowledge is definitive truth. Instead, the best science could be used for was to continually work to better understand the world based on the evidence and interpretations people currently had access to. For Felix, science knowledge was cultural and social, not definitive truth.

All three PSTs started off the Fall Semester in Methods Class with some idea of science as at least partially made up of truths about the world. All three PSTs questioned this idea of how science was related to truth. Alice rejected the idea that science was not made up of truths and reasserted that these truths were determined by professional scientists and communicated in journal articles and textbooks. Willow questioned the idea of science as made up of truths to be accepted from the beginning. Felix questioned the idea that science was made up of truths and explored the idea that everything made and done by humans was inherently tied to individuals' social and cultural influences.

Finding B: PSTs' Frameworks of Teaching

The ways all three PSTs articulated how they thought about their purpose of teaching and the role of the science teacher were connected to how the PSTs thought about what science was and who could do science. All three PSTs reported a shift in how they thought about teaching across Methods Class. Alice and Felix reported shifting from a more teacher-centered view of teaching as communicating the correct curriculum to students who would take this up to a focus on understanding who students were as individuals and valuing student ideas. Willow started with a more student-centered view of teaching and through analysis of the school system as a whole, reinforced her idea of teachers as focusing on students, but more specifically that teachers

should create a humanizing environment in the classroom.

All three PSTs worked to reconcile their frameworks of science with their frameworks of teaching. Alice's frameworks were more difficult to reconcile than Willow's and Felix's frameworks. Alice shifted to a more student-centered view of teaching in which her idea of students as individuals mattering was reinforced by her shifting idea that teaching involved eliciting and facilitating discussion of student ideas and experiences in relation to science concepts introduced by the teacher. While Alice valued student ideas and experiences, there was a tension between this and her frameworks of science as absolute, definitive truths. This meant that student ideas and experiences were valued, but ultimately there was a correct scientific truth that students should arrive at in Alice's classroom. Felix shifted from a framework of science as uncovering truths to a framework of science as grounded in social and cultural contexts. His framework of teaching shifted in parallel ways. Felix first thought of teaching as communicating the one best way to think about Chemistry to students. He shifted to think of teaching as focusing on understanding students' ideas and how they developed those ideas. Both science and student ideas were grounded in social and cultural contexts and Felix saw his role as science teacher being strengthened by a focus on understanding and discussing these contexts and their influences on science ideas. Willow shifted from an idea of teaching as providing access to correct science knowledge to an idea of supporting student use and adaptation of the tool that was science. Willow saw science as a useful tool from the beginning of Methods Class, but she expanded and shifted her idea of what that tool was, how it could/should be used, and by whom. As Willow's ideas of what counted as science and who could do it expanded, so too did her ideas of what it meant to teach.

In this section, I draw from each PST's Science Story editions, Weekly Reflection

Journal entries, and interview transcripts to share how each PST was thinking about teaching across Methods Class and how these ideas were connected with each PST's framework of science and conceptions of science identity for themselves and their students.

Alice - Teaching as Telling to Teaching as Facilitating Pathway Navigation

Alice shifted her framework of teaching from a teacher-centered focus to a more student-centered focus while trying to reconcile this student-centered focus with her framework of science as absolute/definitive truth.

In our first interview, Alice explained how she thought about teaching across Methods Class. She reflected on her ideas of teaching and focused on the component parts of teaching: planning, implementing in the classroom with students, and reflecting afterwards. These were the three processes we (instructors) also broke teaching down into across Methods Class, so it makes sense that these were reinforced. Alice identified a shift in how she thought about teaching across Methods Class. She explained how she thought about teaching before Methods Class:

> Before I took these classes I thought it was like the prep, like you're just, it's heavily the prep and then you show up, and you have a script and you ask your students questions and then they answer the question in the way that you want them to answer it. And then they go home and they remember everything, because you read them a script. (Alice, personal communication, July 20, 2021)

When she first started in Methods Class, she thought most of the teaching happened during the planning portion as teachers created a script of questions that would lead students to think through and learn some information. This aligns with her first edition of her Science Story, in which she stated that she wanted to be a science teacher to share her passion for math and science with her students. Initially, Alice was thinking about teaching as deciding what was important and sharing that with students for them to take up.

Over the course of Methods Class, Alice shifted to think about the majority of work and the most importance being placed on in-class interactions with students. She explained this new way of thinking by referencing a TV show with multiple timelines of events:

> After this class… it's less prep and more in the classroom.…you're in the classroom but you've got all these, "nexus events" is what they're called, … we branch off into different directions. So, you've got the timeline and then …some kids say this and now we're branch[ing] to this way, but in my next hour and other kids said this and now we're branching the other way. So, I'm thinking, … science teaching …. it's more like you're prepping a little bit, seeing what you kind of expect to happen, but then the bulk of it is happening in the class and you're breaking off in different directions and you're not really on a script. (Alice, personal communication, July 20, 2021)

Alice shifted from thinking about the teacher as delivering prepared information in a predetermined way to thinking about teaching as planning for and responding to how students think about the topic or concept. The teacher's role was more of a guide or facilitator or organizer of explorations/conversations. The teacher brought in a particular path of ideas for engaging with a concept and students shared their ideas, experiences, and questions. These student ideas would likely be different in different classes and the teacher's role was to move with students along these different branches created by the interaction of student ideas with the teacher's pathway so the class could explore these multiple ways of thinking through the focal concept. Alice shifted from a teacher-centric view of teaching to a community-centric view of teaching. There was still a main path created by the teacher based on canonical science ideas, but students were expected to interact with and alter this pathway. It is unclear how this would play out and interact with Alice's idea of scientific truths. Perhaps the end goal is to arrive at the predetermined scientific truths, even if the pathway there is different in each class. Perhaps the truths will end up looking slightly different in each class. It is difficult to know at this point. It seems that through Methods Class, Alice shifted some claims about what it means to teach.

This shift toward facilitating students' sharing and exploration of their ideas in relation to a particular topic or concept aligns with how Alice added to her ideas of science teaching in her Science Story. In her second and third editions of her Science Story, respectively, she added that she wanted to teach students how to learn, not just what to learn and that teaching included valuing students' individuality, personal experiences, and ideas, as well as making sure students knew they could be scientists.

Student-centered Teaching and Truth-focused Science. Interestingly, Alice included this idea of teaching as focusing on how to learn rather than what to learn, as well as valuing her students' ideas and experiences and Alice also believed that there was particular information that she had an obligation to communicate to her students. In her weekly reflection journal, she repeatedly stated that as a teacher she had a moral and ethical obligation to connect students to scientific truths backed by data/evidence:

> While people may perceive situations differently, there is still absolute truth. I also think that, as educators, we have a responsibility to help students understand truth in science. There are truths that scientists agree are factual because of long periods of study, experimentation, and in-depth of understanding. Helping students come to understand these known concepts, scientific terms, and phenomena is essential to our role. While it is useful to connect science to students' lives, understand their prior knowledge, and make sense of science, we have a moral and ethical obligation to teach them science from a factual point of view. (Alice, Weekly Reflection Journal, October 15, 2020)

Alice emphasized the need to focus on particular content in the form of scientific truths, strongly stating the importance of this as a moral and ethical obligation. While she wanted to value her students as individuals with experiences and ideas, these experiences and ideas she saw these as separate from the scientific truths so important in the science classroom. Alice restated her belief in absolute truth and science as being based in facts as decided by scientists. Because Alice's framework of science was centered on the idea of science as absolute truths determined by

scientists, a primary part of her framework of teaching/idea of the teacher's role was that teachers must communicate these absolute truths to students. What shifted for Allice was the methods of communication from the teacher preparing a script so students would take it up and understand the given information to talking through/working with students' ideas and experiences in conversation with the knowledge the teacher brought to the classroom and decided students should engage with.

Alice worked to navigate this contradiction between how she thought about science and how she thought about teaching. Maybe who individual people were did not matter in science, as she saw science as absolute truths, but people mattered in teaching. Alice worked with a dichotomy of an objective, dehumanizing, external/unreachable science with a humanizing, people-focused world of teaching. As a teacher, students as individual people mattered and the teacher should help students feel they belonged and their ideas and experiences mattered. As a scientist, there were objective scientific truths which everyone should accept as truth/fact. For example, there are definitions accepted and used by the class because there is a need for a common starting point and Alice thought the easiest, most acceptable starting point is to use what is in the textbook without question. Student ideas and experiences matter insofar as they do not contradict the content/information in the textbook created by experts.

Willow - Support Student Belonging in Scientific Community

Willow's framework of teaching has been shaped by her framework of science and her experiences with science identities, particularly in school. Willow's response to never feeling like she belonged in the scientific community or had a place in science was to become a science teacher who would ensure that her students had experiences that would reinforce their belonging in science rather than their exclusion from science. This was also the advice she offered her

younger brother when he was being made to feel like he did not belong and could not succeed in school. Willow suggested that his experience was unjust and that her brother could become a teacher to create a different experience for students, one where their ideas, experiences, and different ways of interacting would be valued and leveraged to enhance everyone's learning. Willow's overarching goal as a teacher was to support students in feeling like they belonged in the scientific community. In support of that goal, Willow saw her role as teacher as including representing science as done by diverse people, presenting science as a tool everyone can use, and treating students like humans who mattered.

Present Science as a Tool Anyone Can Use. In her first edition of her Science Story, Willow described accessibility as her translating complex science for a younger audience. Willow has access to particular scientific knowledge that was written or communicated in a way that would make it difficult for young people to understand. Willow would translate this knowledge so young people could learn and think about it (and would even know it existed). Willow also wanted "to show students how science can be a useful tool. I want to show them what science can do for them." (Willow, Science Story 1, September 21, 2020). Science is also a tool students can have access to and make use of. Willow also took this a step further to say that not only should a teacher make sure students can understand the science knowledge that currently exists and use the tool that is science, but students should critically question science and be exposed to harm science has done to people. Finally, Willow included a claim about teaching science including helping students to feel that "there is a place for them in the scientific community (Willow, Science Story 1, September 21, 2020).

As she revised her Science Story, Willow refined her claim about teaching as making science content accessible to students through translation to teaching as connecting science

knowledge and the tool of science with student goals in order to further those student goals:

> It's my job as an educator to figure out how my students want to use science, and adapt what I know of canonically accepted science so that they can study science in ways that are useful for progressing towards their individual goals. I think this can be challenging because different students come in with different goals, and some of their goals might be conflicting. I think being the mediator for all of these goals and the science ideas that I am expected to teach is a big part of my job of a science teacher. (Willow, Science Story, December 7, 2020)

Willow shifted from seeing herself as a translator of science for students to more of a facilitator supporting students in making connections between their goals and canonically accepted science. These science ideas were useful and it was her job as a teacher to support students in accessing and applying these ideas to further their personal goals. Science ideas were something students could use in ways that were relevant to their life and it was Willow's job as a science teacher to support students in doing that.

Willow's shift from translator of science to facilitator of science was evident in her Weekly Reflection Journal entries. In one entry, Willow wrote that memorizing terms and concepts was important, but that synthesis of ideas and trying out science practices were also important. These first aspects of science education aligned with her initial idea of teacher as translator of science concepts, but her addition of the importance of students engaging in science practices would necessitate a different role for the teacher:

> Science was mostly about studying and memorizing terms and concepts. I think that this is important, but I think that the synthesizing of these ideas into practice was sometimes lost.… I think that in my own classroom, I want to show students what professional scientists do. I think it would be beneficial for students to learn about how scientists apply these ideas to solve problems in settings such as research. (Willow, Weekly Reflection Journal, September 24, 2020)

In this journal entry, Willow both defended the ways she was taught science with a focus on memorization and posited that synthesis of ideas and actually doing science were important to

include as well. In order for students to try out scientific techniques, a teacher would need to facilitate use of these techniques, which would require different skills than those required to translate science concepts into language students could easily understand.

Willow was starting to consider the idea that teaching involved more than communicating science ideas in a comprehensible way. Willow added, "I think it would be awesome to bring in guest speakers, but I'm not exactly sure how this would fit in with the NGSS standards." (Willow, Weekly Reflection Journal, September 24, 2020). She suggested that she would like to bring in guest speakers to work with her students, but did so hesitantly and with concern that this would not align with state standards. In this journal entry, Willow was first questioning her own experiences and what was acceptable for her to do as a teacher. She had ideas as to how she thought science should be taught, but deferred to authority figures such as her past teachers and possible state standards/requirements. Later in methods Class, Willow was expressing her ideas of what mattered in teaching and what a teacher's role should be in much stronger terms.

Slightly later in Methods Class, Willow made a more definitive statement about the value of memorization in science classes. When asked to reflect on sensemaking in science classrooms, Willow responded, "I feel like sensemaking very much happens in the student's brain. I think that we as teachers guide sensemaking. However, to actually make sense of a phenomenon, it requires active thinking and making connections on behalf of the student. I think that sensemaking is a more active process than just memorizing things." (Willow, Weekly Reflection journal, October 15, 2020). Willow explicitly compared sensemaking to memorization and stated that sensemaking was more active and was required for making sense of a phenomenon. Willow went from defending her experience with science classes requiring memorization as a primary way to learn to edging toward stating that sensemaking was more useful in science than

memorization.

Willow also began questioning the decisions of authority figures in the classroom. When asked to reflect on her experiences in Microteaching, Willow reflected on the use of Ambitious Science Teaching practices and wrote, “I also feel like ambitious science teaching feels a bit scripted now. Although the topics change and how you elicit ideas can change, the actual practice of eliciting ideas seems to follow a fairly strict formula. It made me wonder why we learn ambitious science teaching in the first place, as opposed to other methods of teaching. Why do we follow this format? Why don’t we get a choice over which teaching method we want to learn? Who decided that this was best?” (Willow, Weekly Reflection Journal, October 29, 2020). Willow critiqued what felt like the scripted nature of the practice she was being asked to try out and questioned who decided that this way of teaching was the one to use. Willow did not accept that because instructors expected her to use this practice that it was the best practice. She asked why the practice had been chosen and why she and her fellow PSTs did not have a say in the teaching methods they were learning. Willow was pushing back on authority figures and structures that were telling her how to teach and questioning why she was being told to teach in a particular way. This was an important step for Willow in ultimately deciding that utilizing multiple methods to represent diversity in her science class was worthwhile and something she would do regardless of how she had learned science and what the state standards required. Willow was moving toward requiring evidence for why particular teaching practices were expected or rejected and toward making her own evidence-backed decisions about her teaching practices.

In her third edition of her Science Story, Willow illustrated the confidence she had gained in identifying teaching practices she thought were important. She stated that she wanted to bring

in guest speakers and she did not hedge or question if this was an acceptable practice. Instead, she stated that this was something she would like to do and shared the reasons behind her idea:

> I'd like to bring in scientists I know, as well as community members, to talk about their role in science. I think it would be awesome for so many reasons. You could bring the community into the classroom, you could talk about different STEM careers and hobbies. I think it would be so engaging and fun. I desperately wish I had this when I was in school. (Willow, Science Story, April 20, 2021)

In this section of her Science Story, Willow identified a practice she thought would support her students in feeling they belonged in the scientific community. She explained that she thought this practice would create more connections between students, their community, and possibilities for STEM careers and hobbies. Willow explained how bringing in community members who used STEM would support her students in seeing science as a tool that was adaptable by many different people for many different purposes. This also overlapped with her idea of the importance of diverse representation in the science classroom.

Diverse Representation in Science. Willow identified diverse representation in science as an important part of science education and as part of her role as a science teacher. She had experienced a lack of representation of anyone who she could relate to in science and felt that this contributed to her feeling she did not belong in the scientific community. Willow entered Methods Class with this idea of the importance of diverse representation in science and expressed this in one of her first journal entries in response to a prompt asking what teachers could do to support social justice:

> In my classroom, I want to focus on representing women, people of color, and members of the LGBTQ+ community in science. I want to make sure to use examples from these individuals, and highlight important discoveries that were not made by straight white males. I also want to highlight why it can be difficult to find these examples, including disparities in access to education. I want to include examples of scientific theories from other cultures. I think that talking about science history can

> be an interesting way to bring up social justice issues that still impact science (and the rest of society) today. (Willow, Weekly Reflection Journal, September 10, 2020)

Willow added this idea of diverse representation in the science classroom to the next edition of her Science Story. This included making explicit the ways science has been shaped by historical and cultural contexts, as well as addressing current social justice issues. Beyond simply representing people of different demographics as scientists, Willow added that part of her role as a teacher was to provide multiple ways for students to participate in class. "I think an equitable teacher is intentional about representing different groups of people in their classroom. They offer different ways of participating so that all students feel comfortable participating in class. They consider the cultural backgrounds of their students. They connect science to students' lives. I think this is connected to my goal of making science a tool that is adaptable for different students' lives." (Willow, Science Story, December 7, 2020). Her claim of teaching as providing students access to science became more detailed and shifted from making current knowledge understandable to students to focus more explicitly and specifically on science as something usable and adaptable to further students' goals. Science is not something students have to take up to be successful, but rather, Willow explained science should be something teachers help students take up in service of their personal goals.

In her third edition of her Science Story, Willow shared how being a student in a female professional scientist's class affected the possibilities she saw for herself in science:

> This experience [of getting to know a female scientist as a person] also highlighted to me the importance of representation in science, and not just in books and videos, but in real human interaction. It's one thing to learn about icons like Marie Curie, and this definitely has an important place in the classroom. I've realized that it's different, but also important, to actually know people from diverse backgrounds as scientists. I'm so happy to have had this experience with Dr. Frizzle, but so sad that it had to happen so late in my science career. How would I have felt differently

> about myself if I had a role model that I had a real connection with, like Dr. Frizzle, from a much younger age? (Willow, Science Story, April 20, 2021)

Based on this experience getting to know a female professional scientist and how it benefited her, Willow reinforced her initial idea that diverse representation of scientists was important in the science classroom. She expanded on this idea to emphasize the importance of not only learning about iconic scientists of different demographics/backgrounds, but to get to know professional scientists as people so that students could see scientists as real people they could relate to.

Willow found a role model in her professor, both as a scientist and a teacher. "I want to be a teacher like Dr. [Frizzle]. I want to feel human to my students. I also want to welcome my students into the scientific community. I want to find role models for them. I want to be the kind of person that students want to work hard for." (Willow, Science Story, April 20, 2021). Being in Dr. Frizzle's class was so beneficial to Willow because she could relate to Dr. Frizzle as a person and because Dr. Frizzle made being a scientist feel possible for Willow. Willow felt welcomed in the scientific community for the first time. This was the feeling Willow wanted to cultivate in her classroom with her own students.

Treat Students Like Humans Who Matter. Willow described her experiences in high school and how she thought of her teachers as experts and accepted that following teacher instructions and memorizing given information was a good enough way to learn. Willow was good at memorizing the given information and she was treated kindly and praised by her teachers for doing so:

> It was a lot of teaching to the test and memorizing lots of information outside of class.… The memorization was relatively easy for me, since I had a good memory. I would get lots of praise from my teachers for memorizing the information they asked me to. I thought that since these

> teacher [k]new so much information about science, they were amazing. One thing I know for sure is that whatever my teachers said was law to me. Even though the teaching wasn't the way we're learning to teach now, I still felt like I was learning a lot and I enjoyed the classes. (Willow, Science Story, December 7, 2020)

Willow remembered that her teachers were kind to her and praised her for her ability to memorize given information. In this way, Willow felt like she belonged in the classroom. She felt she learned a lot and her ability to memorize information helped her feel and be treated as successful. Willow later questioned this experience when she wrote about her younger brother's experiences in school. Willow's younger brother, MacKenzie was attending the same school and taking classes with some of the same teachers as Willow. He was expected to do the same kinds of assignments. The difference was, MacKenzie was being treated as not belonging in school, as unsuccessful, unintelligent, and a problem. MacKenzie balked at being given the same kinds of worksheets Willow had done in school, not because he lacked the ability to complete the worksheets, but because he questioned their utility. As Willow wrote in her Science Story, "I've seen the homework he does bring home. They're worksheets that I would consider busywork. The one I remember was a week's worth of practice about a particular vocab word, which was a word [MacKenzie] already knew very well. Still, every day he had to practice doing things like using it in a sentence, coming up with synonyms, and drawing pictures about the word." (Willow, Science Story, April 20, 2021). Her brother's experience in the same school with some of the same teachers Willow had worked with helped her to question what was valued in the kind of education she had experienced and her brother was now experiencing.

Willow explained how she began to question this system of ranking people and their intelligence/value based on grades and what those grades really represented. She asked the question, "What exactly is the difference between me and [MacKenzie] that makes us such

different students?" (Willow, Science Story, April 20, 2021). She then identified what she saw as the main difference between her and her brother, "Our personalities are very different. Does traditional school work better for certain personality types? I honestly think that's the only difference between MacKenzie and I. I'm more compliant and introverted, he's more inquisitory and extroverted." (Willow, Science Story, April 20, 2021). Willow then thought through what this personality difference would mean in the classroom, "He's definitely disruptive in a classroom. I don't mean disruptive in a bad way. He's loud, he's social, he's funny, he's friends with everyone." (Willow, Science Story, April 20, 2021). Willow identified MacKenzie as disruptive, but that this was not inherently negative. He was disruptive to a quiet, structured environment because he was funny and socially engaged. He liked to interact with his peers. Willow did not see a problem with how MacKenzie was as a person. Instead, this led her to the question, "He's brilliant. Why do they just try to force him to be the type of student that I was? Why is that the only type of student that my school values?" (Willow, Science Story, April 20, 2021). When confronted with the idea that somehow her brother was not as smart or valued in school as she was, Willow rejected this idea and instead questioned what type of student was being valued and rewarded in school and why. Why should school be set up to communicate to people like her brother that they must be a different kind of person in order to have value and be rewarded in school?

Willow analyzed her own experience and her brother's experience and came to the conclusion that these teachers treated her kindly because she was more compliant and fulfilled the norms and expectations of school to quietly memorize given information and follow teacher instructions. Her brother was more outgoing and brought in ideas and activities outside of teachers' expectations. As a result, her brother was being treated badly by adults who assumed

the worst of him. Based on her analysis of her own and her brothers' experiences in the same school with several of the same teachers, Willow decided that an important part of being a teacher was to treat students as humans and to value the different ways of being and knowing that students brought to the classroom.

One of the things Willow thought teachers could do to value students as humans was to stop treating students like numbers and using grades to assign worth. A question her brother raised for her was why grades were used to assign value to students and what this did to students' feelings of self-worth. Willow looked back on her own experiences in high school and explained how this number system was harmful to everyone, including students deemed "successful":

> My whole life, especially in high school. I was often literally told I was number 1. I think that turned me into a person who had a hard time empathizing with other students' experiences. I really believed that I was better, and that is was because I was smarter and worked harder than everyone else. That was the message that was constantly reinforced my whole life, it makes sense why I believed it for so long. (Willow, Science Story, April 20, 2021)

Willow identified how she thought about herself and other students based on the system of assigning students a number that supposedly represented their value. She went on to identify on-going problems with this system of assigning worth through academic rankings when she noted that, "I also have to work on not basing my self-worth on my academic achievement." (Willow, Science Story, April 20, 2021). When someone's self-worth is based on academic achievement, having difficulty in a topic or class becomes a bigger issue than simply needing more time and/or support to understand or become proficient in something, instead, it is an indication of your value or lack thereof as a person, as Willow explained, "Despite what my school probably expected, thinking I was smarter than everyone because of my GPA and ACT score actually wasn't great for my mental health in the long run" (Willow, Science Story, April 20, 2021).

Willow also added, “I think telling someone they are better than everyone else is also extremely damaging, because you create people who hurt people.” (Willow, Science Story, April 20, 2021). By creating a hierarchy of people and their value, this instilled the belief that some people are better and more valuable than others, which is a step toward justifying differential treatment of people based on grades or test scores. Willow also identified and analyzed the negative effects of being one of the students who was identified as smart and superior to others. She called this “honor student culture” and explained that as someone with this culture, she:

> had to take the hardest classes possible. I had to do extracurriculars, as many as possible. I was sleep deprived for most of high school…. My days were completely packed from 6 am to 1-2 am, except for an hour or two break when I got home after cheer practice. I was always disappointed with myself for taking such a long break and thought that my lack of energy was a lack of willpower.… I’d wake up in the middle of the night face down in a textbook with flashcards stuck to my face. I thought this made me cool for working so hard…. I thought being too busy to eat was cool. I looked down on people not doing these things for not “working as hard”. All these beliefs and behaviors were reinforced by my school and family. I was constantly used as the good example, which again reinforced my ego. (Willow, Science Story, April 20, 2021)

Willow identified expectations that students would accept adult authority without question and take pride in being too busy to sleep or take care of their mental and physical health as inherently harmful. She explained the problems with these expectations for her brother and herself and challenged the need or benefit of these norms/expectations. Willow did also state that not everything about this experience was negative for her. “I am still very proud of how much I accomplished and how hard I worked. I certainly don’t think it was healthy though, and I wouldn’t encourage anyone else to live this way. It certainly wasn’t a sustainable way to live.” (Willow, Science Story, April 20, 2021). Willow was not saying that she got nothing out of her time in high school. She accomplished many things. She worked very hard. And the way she did this, was expected to do this, and was celebrated for doing this was not healthy for her.

As Willow analyzed her ideas of what it meant to teach, she reinforced her commitment to welcoming students into the scientific community through diverse representation, connecting science to their lives and goals, and critiquing the dehumanizing school norms and practices that labeled students as successful only if they conformed to narrow expectations of participation.

Felix - From Forcing Epistemologies to Creating Scientists

Felix's framework of teaching shifted in parallel with his framework of science. As he questioned and revised how he thought about science and what doing science meant for humans, he also questioned and revised what he thought his purpose of teaching was. Felix initially expressed that he thought of science education as a passing down of knowledge that would make people smarter. By the end of the Fall Semester, about halfway through Methods Class, Felix was questioning this idea of knowledge transfer and shifting to focus more on the process of science rather than particular content. By the end of the second semester of Methods Class, Felix had adjusted his ideas of teaching to include the importance of culture, personal connections, questioning norms, and valuing multiple epistemologies in the science classroom.

Felix described these shifts in his ideas as moving from thinking that being a teacher meant forcing his own correct epistemologies onto students to thinking that being a teacher meant "creating an army of liberal scientists" which to him meant supporting students to be scientists by engaging in thinking, questioning, and creatively exploring and explaining the world. In particular, he recognized that he initially thought about teaching as saving students by providing them with the correct way to do and think about science and over the course of Methods Class, he recognized this belief, questioned it, and adjusted it to align with his current perspective of teachers and students. Felix described this in an interview the summer after Methods Class had ended by sharing two anecdotes that he thought captured how his framework

of teaching had shifted in the past year. He began by referencing a conversation he had had with two of the Methods Class instructors (Timothy and me):

> So, when [Timothy] and Sinead both inquired about an anecdote I used to convey some idea about my motivation behind education, the starfish story about…a girl who was picking up starfishes to throw them back into the ocean to 'save them' from dying…. So, the anecdote stems from the suffering I experienced in my educational career…. (Felix, Interview, July 23, 2021)

Felix shared how he had thought about teachers as saving students, much like the child in the Starfish Story saved the starfish washed up on the shore by throwing them back into the ocean. Maybe he could not save all of them, but he could make a difference for some individuals. He then explained what he remembered of how we (instructors) responded to his sharing of that particular anecdote as representative of his purpose as a teacher:

> However, when we first kind of talked about it and I mentioned it, you… kind of pushed back on that anecdote…and I didn't really know why until actually quite recently when I read this book…. "*So, the work for teachers becomes developing the self reflection necessary to deconstruct the ways that media messages and others teachers' negative and often exaggerated stories and their own need to be the hero affects how they see/teach students."* (Felix, Interview, July 23, 2021)

Felix remembered that we (instructors) pushed back on his use of this anecdote to represent his teaching purpose. As was common in our conversations with PSTs, we (instructors) asked Felix questions about why he felt that particular anecdote best captured his purpose of teaching. If the starfish represented students, what did they need saving from and why did he think so? While Felix did not immediately understand why we asked these questions, they stuck with him and when he read a book outside of class called, "For White Folks Who Teach in the Hood…and All the Rest of Y'all Too" by Christopher Emdin (2016), there was a particular passage that resonated with him and helped him think back to the Starfish anecdote, his purpose of teaching,

and the questions we (instructors) had asked him. Felix then shared his new interpretation of the questions we (instructors) had asked him about his teaching purpose and the Starfish Story:

> So, you are cautioning me as viewing students, specifically youth, youth of Color as needing saving, because…I said they needed saving. But it was biased towards my definition of who should be saved…for what reason. So, it was another avenue for me just enforcing my beliefs and values onto other people… I still struggle… because I do…want to help. But now I try to caution myself in how I help, and why. And I'm more trying to default to just understanding…where people are coming from and what people are trying to say… (Felix, Interview, July 23, 2021)

Felix explained how he drew from our conversation about his initial purpose of teaching and the passage from Emdin's (2016) book to examine his ideas of teaching, question those ideas and adjust them. He recognized that his initial idea of teaching was based on an assumption that students needed saving, that the teacher's role was to save students, and that this meant he as a teacher would be pushing his own values and experiences onto students without considering their goals, ideas, and values. Felix described this realization that he did not want to be someone who pushed his own beliefs and values onto others. He shifted his idea of teaching toward questioning why and how he helps people and focused on trying to understand people's experiences and ideas rather than telling them what those ideas and experiences should be.

Felix identified this paradigm shift related to his purpose of teaching. In the rest of this section, I examine how Felix's paradigm shift occurred over the course of our Methods Class, drawing from his Science Story editions and Weekly Reflection Journal entries.

Matching Purpose and Practice. Felix first thought that the role of the teacher was to pass down knowledge, but he also questioned which knowledge and what passing down knowledge meant for students and for science. He determined that if the teacher's role was to pass down knowledge, then the student's role was to memorize that information and this did not align with how Felix thought about what science was or what it meant to be a scientist. Felix

shared in an interview after Methods Class that he thought of scientists as “thinkers, learners, and questioners” (Felix, personal communication, July 23, 2021). Memorizing given information did not fit with this idea of scientists. Felix shifted away from thinking of the teacher’s role as passer down of information to maker of scientists. Felix described how he was, “struggling with…my purpose…what I thought it was supposed to be doing. But what I was actually doing, was it useful?.... I thought it was supposed to be passing down knowledge.” (Felix, personal communication, July 23, 2021). Felix recognized that he was caught up with what he thought he was supposed to be doing as a teacher, but then he asked himself if what he was doing was useful. He identified that he thought he “was supposed to be passing down knowledge” but then he shifted from thinking about what he thought he was supposed to do toward what he thought he should do as a science teacher as he explained:

> But then I changed towards, well, maybe I should be making scientists. Well, what does that mean? Who are…scientists, right? And then I realized that, yeah, I'm supposed to be making scientists but scientists don't- aren't just, you know, some chemist in their ivory tower doing science….it just means someone's who's critical about … the question, the status quo and then question everything. So, the next sticky note was like to create scientists, but then I realized the method…matters. And that's, I feel like when I really started struggling with how- how I'm teaching, and how that represents…my purpose… and if those aren't aligned, you're not doing anything. You're fighting against yourself or you're not accomplishing what you're trying to do. And then I realized that what I was doing was creating an army of liberal scientists. [I] think that's what I was doing. (Felix, personal communication, July 23, 2021)

Felix thought that as a teacher, he should be making scientists and then he asked himself what it really meant to make scientists. He considered and rejected an idea of scientists as people who are outside of the general population, who do science in isolation and instead drew on a broader definition of scientists as people who question everything. Based on this definition of what a scientist is or who a scientist is, Felix asked himself what that meant for his practices as a

teacher. Felix was considering how his teaching methods supported students in becoming scientists or not and stated here that his teaching methods needed to align with his purpose.

To support students in acting as scientists, a teacher was required to be something other than the expert source of correct knowledge in the classroom. The teacher was instead a facilitator of student questioning/sensemaking. Felix did not want students to simply take in given information without question, but instead he saw science teaching as encouraging students to question everything, to have the skills/practices to ask questions and explore reasons and explanations. Felix expressed the importance of his teaching practices aligning with his purpose of teaching. As he shifted to think about his purpose of teaching being to "make scientists" he had to shift away from his idea of teacher as disseminator of knowledge because scientists did not unquestioningly accept information as truth. Scientists asked questions and thought through information, where it came from, how it was generated, based on which evidence, and if there could be an explanation that better fit with the evidence or if there was additional evidence that should be considered. This kind of questioning was what Felix determined he should support as a science teacher who made scientists. At the very least, his purpose was to not prevent or inhibit the creation of scientists through expectations of memorization or adherence to a strict curriculum. Felix recognized that "forcing" students to be like him in terms of unquestioningly taking up information he passed down to them as truths went against what he thought it meant to be a scientist and Felix did not want to do this as a science teacher. The question is, how did Felix get from a belief in the science teacher as passer down of knowledge to this idea of the science teacher as facilitator of student questioning?

Teaching to Fix Past Wrongs. Felix's idea of teaching as saving students was tied to his own experiences in the classroom in which he felt that he was presented with a false and inferior

view of what science, and Chemistry in particular, was. His initial solution to this problem he had experienced was to work in curriculum development to make sure all students had access to the same high quality Chemistry curriculum. Felix thought that if all students had access to the same curriculum, they would all have the same opportunities to engage in and pursue science, which would address inequities he saw and experienced in school.

I noticed this shift across Methods Class in Felix's Science Story editions and Weekly Reflection Journal entries. In one of Felix's first journal entries, in response to a prompt about how teachers could work toward social justice, Felix identified social change as a reason he decided to pursue a career in education, specifically curriculum development:

> Social change is why I have decided to go into curriculum development, I think that by developing ethical and effective curriculum I can help fight against systemic racism in our schooling system. What does equitable science education mean? I find it helpful to consider that equitable science education disadvantages no one, opening the doors of science to anyone. In the past and present, everyone's high school diploma is not equal, because people's education is not equal. By developing the best curriculum for students to learn from, I hope to shrink the differences in education quality. (Felix, Weekly Reflection Journal, September 10, 2020)

He believed that by producing the best curriculum and making sure all students had access to this curriculum, he could help level the playing field for students across different backgrounds. Felix wanted to work toward equitable science education, but had fallen into the thinking of equity as access and inclusion, which (Calabrese Barton & Tan, 2020) have explained is unjust and requires students to give up parts of themselves to gain this access.

In addition to this, Felix was also already thinking about the importance of students as individuals with different ideas. He also expressed the idea that students making sense of given science information was important and better than rote memorization. "I believe that the formation of ideas in the students is paramount for their success as students and lifelong

learners.… This also avoids present knowledge in a Eurocentric, white male perspective, and changes it to the perspectives of each student individually as they are forming their own knowledge." (Felix, Weekly Reflection Journal, September 10, 2020). Here, Felix brought up what he saw as the importance of focusing on student ideas and students making sense of knowledge rather than just taking in lists of facts. He connected this to ideas of justice when he further implied that focusing on student ideas would necessarily involve students relating the ideas from science class to their own perspectives, which Felix assumed would be different from Eurocentric, white male perspectives. Even as Felix focused on the importance of creating a single best Chemistry curriculum that would be utilized in all Chemistry classrooms, Felix also expressed the importance of individual perspectives, experiences, and ideas in the classroom. At this point, Felix thought that giving all students access to the same high-quality curriculum would improve science education and create social change. This made sense based on Felix's own experiences in school science as he expressed in his first Science Story edition:

> My Chemistry class … was awful and I hated Chemistry when I was in high school. I come to college … and I fell in love with Chemistry. I love it and it made me angry that I hated Chemistry for that long…. Like, ok, what if my high school was taught like this class, instead of how it was originally taught. And I feel like that's a major driver for me…. If students can't access the best resources, that's a problem, in my opinion." (Felix, Science Story, September 21, 2020)

Felix explained in his Science Story that part of the reason he wanted to be a Chemistry teacher and develop curriculum was because in his high school Chemistry class, Chemistry was treated as abstract facts to memorize and he hated this. When he got to college, Chemistry was taught as a system of knowledge and Felix found it fascinating and useful and fell in love with Chemistry. Felix was angry about the way he was introduced to Chemistry and that this did not align with what he came to learn Chemistry actually was. Felix was determined to fix this problem and

prevent others from potentially being kept out of Chemistry the way he almost was. Felix thought that if all Chemistry teachers used a curriculum that presented Chemistry as this rich system of knowledge, this would address the issue he encountered as a high school student. Felix's initial focus was on solving a problem he had experienced and as he felt he had encountered the correct way to think about Chemistry, the obvious solution to him was to create a curriculum that passed down that correct way to all students so everyone had equal access to Chemistry.

Felix was focused on what was communicated to students and that they had opportunities to make sense of this knowledge, but had not yet questioned if the exact same curriculum as determined by him would actually be best for all students. If his goal was to pass down this correct version of Chemistry, then his identical curriculum for all might serve that purpose, but as became evident in his later journal entries and Science Story editions, this identical curriculum for all idea did not align with his other ideas of the importance of individual sensemaking and valuing multiple perspectives.

Sensemaking. Felix was very clear that students should be supported in making sense of concepts. "You can NOT learn for other people, that is not how it works. We construct our own knowledge, and to 'change thinking' or rather help a student activate different resources, the student must take charge of that change." (Felix, Weekly Reflection Journal, September 17, 2020). The teacher could provide different resources to engage with, but for learning to happen, the students needed to think through and engage with those resources. This idea of the importance of sensemaking meant that Felix always questioned the utility of presenting facts to be memorized in science class. Felix valued individual student thinking.

At the same time, Felix believed that there were better, more correct, or more "expert-

like" ways to think in science. He explained a connection he saw between professional science and classroom science, "Experts inform us educators on how they think about science, which helps us lead students to think like an expert. This is important because one of our goals is to turn novice thinkers into experts like thinkers." (Felix, Weekly Reflection Journal, September 24, 2020). Here, Felix assigned professional scientists the role of "expert" and identified the way these experts thought to be the way educators and students did not think. But that educators could learn to think this way and then help students learn to think this way as well. This was an example of what Felix later identified as his goal of forcing his own epistemology on others. He, and other educators, had the correct way of thinking, which came from professional scientists, and educators had to get students to adopt this way of thinking.

Questioning his Initial Ideas on his Purpose of Teaching. Felix had started to question and rethink his purpose of teaching partway through the Fall Semester of Methods Class, as evidenced in his Weekly Reflection Journal entry on the role of sensemaking in science education. Felix defined sensemaking as "the process of adding new knowledge to your conceptual framework, which is inherently learning…. prior knowledge must be reconciled with in some way to add a new resource." (Felix, Weekly Reflection journal, October 15, 2020). Felix added a statement about his shifting goal in science education, writing, "my goal is for students to learn. Learn what? I do not know. Science, science epistemology, no. Sensemaking skills, perhaps." (Felix, Weekly Reflection Journal, October 15, 2020). Felix expressed a rejection of teaching students what he labeled as "science epistemology" to consider instead a focus on "sensemaking skills". It seems that at this point, Felix was thinking of "science epistemology" as different from "sensemaking skills". Felix was considering that maybe his goal as an educator was not to teach a particular way of thinking he had identified as science epistemology, but to

teach students how to think through and reconcile their own prior knowledge with new ideas and experiences. That Felix focused on sensemaking skills implied a focus on ways to make sense of new knowledge, ideas, and experiences rather than focusing on particular ideas of experiences. This was a focus on process over particular content.

When reflecting on his Microteach experiences, Felix noted that a way to support sensemaking skills could be through using a phenomenon to elicit student ideas, "I have never taught material using a phenomenon to elicit student ideas. I feel as though this teaching practice has validity and wil find a place in my curriculum." (Felix, Weekly Reflection Journal, October 29, 2020). Felix reflected that he had not considered using a phenomenon to elicit student ideas before, but that after trying this out and seeing his peers try out different ways of using phenomena to elicit student ideas, he thought this practice was valuable and he planned to take it up and include it in his curriculum. Felix was still focused on, and was actively thinking about what to include, in this curriculum. Felix also stated, "I have begun to question the positioning of my knowledge within this micro-teach and have yet to reach a conclusion." (Felix, Weekly Reflection Journal, October 29, 2020). Felix noted the questioning he was doing and that he was in the midst of it. Perhaps his knowledge was not the only knowledge that mattered in the classroom, but he was not sure. This was expressed in the same journal entry on the importance of eliciting student ideas and that generating ideas the teacher had not expected was not a bad thing. There could be value in these unexpected ideas.

Starting to Recognize Multiple Ways to Think/Do Science and Teacher Power. In his Weekly Reflection Journal entry toward the end of the Fall Semester, Felix stated that, "Science is made of questions, observations, hypotheses, and curiosity and science teaching involves the facilitation of science." (Felix, Weekly Reflection Journal, November 2, 2020). At this point,

Felix was writing about teaching as facilitating student questioning, observing, forming hypotheses, and being creative. This was a clear focus on specific, but broad processes of science, rather than his previous focus on a general, unnamed "expert-like" way of thinking about science which needed to be passed down to students by the teacher. Now, there was a focus on facilitating student engagement in these particular processes of science. Felix also reflected that the scenarios we discussed in class that day raised questions for him, "about how science is represented and the framing of knowledge within science," (Felix, Weekly Reflection Journal, November 2, 2020). The scenarios each provided an example of interactions between an educator and students with different frameworks of science. In some cases, the educator and/or students recognized and valued the different frameworks and their underlying experiences. In other cases, the frameworks remained implicit and the educator treated the knowledge generated with their own framework as correct and the knowledge based in the student's framework as incorrect. This raised questions for Felix about how science was framed and represented and he further stated that he, "believe[d] science should not be authoritative but collaborative, within a classroom, teachers can hold significant power in the realm or knowledge and the ownership of that knowledge. Great care must be taken with that knowledge." (Felix, Weekly Reflection Journal, November 2, 2020). Felix recognized that there were multiple ways of thinking about and explaining phenomena based on people's experiences and individual interpretations of observations and other evidence and that teachers could exercise power in the classroom to validate/reinforce or invalidate/devalue knowledge. Felix thought that teachers needed to be careful with how they wielded this power and that in science there should be collaborative sensemaking rather than one authoritative view of which frameworks of science/knowledge were valid. Here, Felix was shifting from the idea that there was one correct way of doing/thinking

about science as determined by the teacher or curriculum and toward his later idea that teachers should support students in engaging in science, in questioning, rather than only taking up the way of doing/thinking about science that was familiar to the teacher.

Toward the end of the Fall Semester, Felix was grappling with his initial goal for becoming a science educator and questions about his intentions behind this goal that were being raised in Methods Class activities. In his Weekly Reflection Journal, in response to the prompt asking what his burning question was about science teaching, Felix wrote, "Is there a 'correct' or rather best way to teach science (discipline specific)?" (Felix, Weekly Reflection Journal, November 24, 2020). Felix elaborated on his question, "I have always held the notion that science can be taught in a certain way, which can allow knowledge building and knowledge transfer to happen in the most effective way. Effective in this context, means that…the most students retain and use their new found knowledge." (Felix, Weekly Reflection Journal, November 24, 2020). He explained his broader purpose as, "to lift those around me to a greater academic level, or ability allowing the human race to advance toward greater achievements." (Felix, Weekly Reflection Journal, November 24, 2020). Felix expressed his goal/idea of improving the abilities of others to advance the human race as a whole. It was interesting that Felix asserted strongly that people must and can only learn for themselves and as a teacher he would facilitate sensemaking skills while also going back to his idea of being a person who improved others, implying they were not good enough to begin with and he specifically was the one to decide what improvement entailed. This notion was what Felix later reflected on as his initial paradigm, which he had shifted away from by the end of Methods Class.

Halfway through the class, he was still grappling with this idea and even while he questioned his idea, he asserted it even more strongly. Felix stated in this same reflection,

"Maybe my original idea was problematic, I tried quantifying the abilities of the average human in terms of intelligence, ability, without consideration of context." (Felix, Weekly Reflection Journal, November 24, 2020). Felix questioned his original idea and the quantification of human intelligence and ability. He considered that perhaps quantifying intelligence and seeing teaching science as a way to increase intelligence, as well as ignoring context were problematic. Felix then immediately negated this questioning to reassert his ability to improve Chemistry teaching and advance the human race, "But regardless of the context, I believe that I can advance the way of teaching chemistry toward a methodology which is effective. I understand that people have different purposes for education, but I also believe that those purposes are in-correct…. the only thing that matters is the advancement of the human race, nothing else, just that." (Felix, Weekly Reflection Journal, November 24, 2020). Felix posited that perhaps context was important and then immediately stated that he thought there was a way for him to improve Chemistry teaching and his purpose was the correct one. Here, Felix reasserted his idea that he had superior knowledge as to how and why Chemistry should be taught and that he could develop a way of teaching Chemistry that would advance the human race. Felix briefly questioned and then restated this purpose of his as a science educator. It made sense that Felix would reassert his initial framework of science teaching even as he was beginning to more clearly articulate it and question some of the claims that made up this framework. This framework of his purpose of science teaching was important to him. It was not something to be abandoned or adjusted easily. Felix was doing exactly what we (instructors) hoped he would do in Methods Class: articulate his framework, consider what ideas/claims supported his framework, from which experiences these claims were derived, question and examine these claims alongside claims and experiences of others.

Explicitly Recognizing and Articulating Ways Felix Exerted Power as Teacher. By the very end of Fall Semester, Felix was still actively grappling with his ideas of what was correct scientific knowledge and what his role should be as a science teacher. When asked to reflect on the evidence he used as a teacher to explain phenomena, Felix wrote that he drew from "historical evidence from the scientific community to develop theories and models…it can show the history of human knowledge and how we resulted at our current understanding about the world." (Felix, Weekly Reflection Journal, December 3, 2020). Felix noted the importance of understanding the historical context of currently accepted scientific knowledge. Felix immediately complicated his initial response by further writing, "Of course, I generally use knowledge generated from western society and often do not investigate the understanding of other cultures, which is problematic in showing the true journal humans have gone through to gain our current level of understanding as well as sustain historical injustices around who can 'do' science." (Felix, Weekly Reflection Journal, December 3, 2020). Felix identified his tendency to rely on scientific knowledge from one particular cultural perspective, one with which he was most familiar, and the limitations of excluding knowledge generated in other cultural contexts.

As he continued to write, Felix named part of his process of looking for evidence to explain phenomena as, "look[ing] at evidence which will allow myself to push forward students' understanding of concepts within science and challenge students to make sense of the world around them." (Felix, Weekly Reflection Journal, December 3, 2020). Felix wanted to provide evidence that would prompt students to make sense of the world and support their understanding of science concepts. He then questioned what particular understanding he was supporting and acknowledged the role/power teachers exert in their selection of evidence to share with students

and in what ways and how that could shape how students interact with evidence and interpret the world when he wrote, “Although, I probably just look for evidence which will help myself push my own agenda onto other people.” (Felix, Weekly Reflection journal, December 3, 2020). Felix explicitly recognized the power he could exert as a teacher to shape the knowledge/ideas and evidence that were interacted with in the classroom. This represented Felix’s recognition and questioning of this role of the teacher. By acknowledging this reality, Felix could grapple with it and decide to actively continue doing this or to change his practice.

Felix Recognized the Importance of Multiple Epistemologies. A few weeks into the Spring Semester, Felix wrote about his shifting ideas of his purpose/role of teaching. Felix laid out his ideas of science, “Despite the appearance of scientific neutrality, all knowledge is held in a certain set of values and beliefs, as knowledge is built in a context, affected by culture and society; therefore, the knowledge building process of science is a social enterprise, affected by the beliefs and values of those who create such knowledge.” (Felix, Weekly Reflection Journal, February 5, 2021). He stated that science was not neutral, but shaped by the contexts of the people who created scientific knowledge. He further went on to tie this to how educators interacted with students and their epistemologies:

> In teaching and learning, if frameings are not acknowledged and understood, certain ways of knowing are ranked higher than others, creating a classroom environment with an oppressive view of other ways of knowing. If we as educators do not understand that our knowledge is embedded within our individualistic experience of reality, then we may begin to oppress our students’ individual epistemologies about the world, alienating those who do not align with my values and beliefs. (Felix, Weekly Reflection Journal, February 5, 2021)

Felix more directly/explicitly explained that recognizing the existence of multiple epistemologies was important and to not recognize and value these epistemologies would result in a form of epistemological oppression. Felix then connected these ideas of multiple epistemologies and the

need for recognition of the individuality and contextual nature of each person's epistemology to his shifting ideas of his purpose/role of teaching:

> I once more shift towards a different framing of education and my purpose within the education systems. Using frameings I can analyze my knowledge about other ways of thinking and begin to postulate why my previous ways of thinking about other's epistemologies may not have painted a full picture." (Felix, Weekly Reflection Journal, February 5, 2021)

In this Weekly Reflection Journal entry, Felix noted that his ideas of his purpose of teaching were shifting as he considered that perhaps he did not have as clear of an understanding of multiple epistemologies as he had once thought. Through thinking about framings (what we called "frameworks" in our class) of knowledge, he questioned what he did and did not know about different ways of knowing. This was a move away from his previous idea that he could create one best Chemistry curriculum for everyone and toward a more expansive idea of whose ways of thinking/knowing should count in science education.

Multiple Epistemologies/Framings/Frameworks and Equitable Teaching. Felix explicitly explained his thoughts on science, multiple epistemologies, and the teacher's role in a Weekly Reflection Journal entry in the first half of the Spring Semester when asked about framings/frameworks of science. Felix wrote, "Acknowledging there is a different way of looking at the world is something I believe that every human being should accept…. When we consider our framings and the framings around us, we participate in acknowledging that there are different ways of looking at the world that have equal value to our own…." (Felix, Weekly Reflection Journal, February 12, 2021). Felix stated the importance of valuing multiple framings/frameworks and then connected this to his role as a teacher, writing, "If we, as educators acknowledge and present different framings of science…. we help increase the access of students who bring different perspectives about the world, as well as hopefully acknowledging

different views are valued in our classrooms. So, bringing multiple framings of science, we not only increase the equitability of our classrooms, but we seek to disrupt historical inequities within the schooling system." (Felix, Weekly Reflection Journal, February 12, 2021). In his initial framework of teaching/idea of the role of the science teacher, Felix included an idea of equity through providing all students with access to the same high-quality curriculum. In this journal entry, Felix wrote about a different way to create an equitable science classroom, that of bringing in and valuing multiple framings/frameworks of science in the classroom. This idea did not invalidate his initial idea of creating a high-quality curriculum, but it did provide a specific way to create a more equitable classroom beyond implementing the same science curriculum in all schools. This new idea of Felix's could be included in a curriculum, but was more of a way of thinking about science and the role of the teacher than a specific, prescriptive component of a curriculum.

Teaching Includes Addressing Sociopolitical Issues and Reducing Harm. Felix expanded what he saw as the teacher's role from passing down particular scientific knowledge to facilitating sensemaking about the world and to explicitly include sociopolitical issues. He reflected, "I believe that courageous conversations will become an integral part of my classroom. Preparation for such conversations is necessary as they will happen regardless of my desire for them to be or not, I therefore must embrace those conversations in ways which promote learning and a safe environment. I have realized that you cannot control what students say, but teachers can take steps to decrease the probability that students will inflict and receive harm through classroom discussions." (Felix, Weekly Reflection Journal, April 2, 2021). Felix added to his teacher role the practice of facilitating discussions of sociopolitical issues as these were relevant to, and part of, his students' lives. Addressing these issues before and as students brought them

up and making sure students were not harmed by these conversations were part of this facilitation. This did not mean making sure students were comfortable, as these conversations can be very uncomfortable, but that things like harmful stereotypes were not expressed by a student in a way that would negatively impact another student who belonged to the targeted group.

Felix summed up his thoughts on his role as a teacher in his final Weekly Reflection Journal entry:

> Well, I am not thinking about enforcing my epistemologies onto other people so that is great. I see myself using ambitious science teaching practice in my classroom, I want the teaching I do to be reinforced by a purpose, I want a purpose for everything I do. I want my classroom to be a holistic representation of the cognitive work scientists do, I also want to assist students in forming an understanding of what science is and what it can do, informed by historical accounts and personal experiences. I want teaching in which students hold epistemic agency, students who hold power in what our classroom culture looks like. I see the knowledge being formed in my classroom as having applicability to students' lives, which may be accomplished by motivating what is learned by student desires and experiences. (Felix, Weekly Reflection Journal, April 21, 2021)

Through articulation and questioning of his ideas of teaching and the experiences and interpretations that supported these ideas, Felix shifted from an assimilationist framework of teaching with claims as to what and how students should learn science to a more justice-oriented teaching framework. In this revised framework, student ideas, experiences, and goals were valued, cultural and social contexts of science and students were recognized, engaged, and seen as a strength in the classroom.

Teacher's Role Across 3 Focal PSTs

All three PSTs started with an idea of teaching as communicating particular science ideas to students in a way that students could easily take up these ideas. Alice thought she needed to create a script of questions, Willow thought she should translate complex ideas into simpler

versions, and Felix thought he needed to find the best way to communicate the correct way of thinking about Chemistry. Throughout Methods Class, all three PSTs shifted to ideas of teaching that were more student-centered, which included valuing the ideas and experiences that students brought to class. Alice ended up thinking of teaching as facilitating student discussions around points of intersection between their own ideas and experience and the science ideas she would bring to class as the teacher. Willow focused more on her idea of science as a tool and solidified her claims that teaching should focus on welcoming students into the scientific community by showing students that they belonged and that they could adapt the tool of science to further their goals. Felix saw his purpose of teaching as creating "an army of liberal scientists" or supporting students to think and question everything. All three PSTs were focused on supporting students in deepening their understanding of the world through science. Alice wanted to facilitate students in drawing from their own experiences to think through and understand canonical science ideas. Willow wanted to support students in seeing themselves as scientists who could use the tool of science to better understand and act in the world. Felix wanted to support students in becoming scientists through continual questioning of the world. At different points in Methods Class, all three PSTs included getting to know students as people with varying ideas and experiences as important to their work as teachers.

Summary of Focal PSTs' Science and Teaching Frameworks

All PSTs left Methods Class with a more student-centric view of teaching, though their views of teaching interacted in different ways with their views of science. This student-centric view of teaching did not always align with the PST's framework of science. The alignment or differences between the PSTs' ideas of teaching and framework of science were tied to each PST's identities.

Alice: Universalist Science and Student-centered Teaching as Groundwork for Assimilationist Teaching

Alice's combination of a universalist framework of science and a student-centered framework of teaching meant that Alice would likely either teach in an assimilationist way (Mutegi, 2011, 2013) or continually feel pulled between valuing her students' ideas and feeling an obligation to get them to take up the "right" scientific knowledge from "experts". Alice reinforced her idea of science as absolute truths while expanding her idea of what it meant to teach and how student ideas should be treated. Alice started with a notion of teaching as telling. By the end of Methods Class, she described teaching as co-creating knowledge with students through facilitating students in bringing their ideas and lived experiences to class and using them to interpret and engage with the phenomenon or science concept the teacher introduced to the class. Alice moved toward an assets-based view of students (Tuck, 2009), but did not accept the social, cultural, political, and historical dimensions of science and that privileging science done by a particular group of people perpetuated injustice in the classroom. Alice struggled with a conflict between her framework of science and her new framework of teaching. It was difficult to reconcile her beliefs in the value of individual student ideas and experiences with her belief in science as a set of absolute truths about the world. Student ideas could only matter insofar as they were useful in eventually helping students understand the "factual" science knowledge that came from experts and was communicated in textbooks. Alice's framework of Eurocentric science as universal truths was tied to her ideas of who could be a scientist. Scientists were smart, special people who studied a particular subject or phenomenon for a long time in rigorous ways so they could determine truths about the world. Believing that there were experts she could trust who knew the truths of the world was important to Alice. Leaving the deciding about what

was truth to these experts removed responsibility from Alice and others to determine what was truth themselves. This was comforting and important enough to Alice that she resisted questioning why she believed this about science and scientists. While her framework of science as universal, absolute truths was comforting to her, it conflicted with her shifted student-centered teaching framework. Alice may have already felt this conflict as she decided not to pursue teaching toward the end of Methods Class.

Willow: Teaching as Welcoming Students into the Scientific Community and Science as a Tool for Pursuing Personal Goals

Willow's frameworks indicated a shift toward a more multicultural and critical view of science and teaching in line with justice-oriented science teaching. Willow moved away from an assimilationist view of science teaching and toward a justice-oriented framework of science teaching in which the tool and knowledge of science were questioned and adapted to serve people's particular needs. While she did not label her teaching as centered on social justice science issues (Morales-Doyle, 2015), her focus on centering her science class on goals important to her students and supporting students in using science to do things that mattered to them aligned with the spirit of what Morales-Doyle (2015) termed "justice-centered science teaching" and aligned with our notion of justice-oriented science teaching in its focus on science as social, political, and a tool for students to use to act in their communities as "transformative intellectuals".

Willow also tweaked her idea of teachers as providing access to science and welcoming students into the scientific community when she shifted from seeing teaching as providing accessible explanations of existing scientific knowledge to seeing teaching as facilitating students' use and critical questioning of the tool and knowledge of science to serve their own

goals. This was reinforced by her science identity work as she was recognized as skilled in science and a scientist by a female science professor who acted as a "meaningful other" (Carlone & Johnson, 2007). She started Methods Class with an idea of representation in science as important for students feeling welcomed into the scientific community and like they could be scientists. Her experiences in her university science class with a female scientist who Willow connected with as a person, were incredibly important for Willow's science identity work. This experience was tied to details she added to her idea of teachers as welcoming students into the scientific community by making sure students saw themselves represented in science. Willow's experience aligns with Mensah and Jackson's (2018) ideas that representation in science is important for pursuing both science and science teaching. Mensah and Jackson (2018) focused on the importance of representation of scientists of Color, especially female scientists of Color. The same idea held true for Willow as a woman in science. This calls attention to the importance of representation in university science classes both for students to directly pursue science and for preparation of science teachers who break the cycle of exclusion of people of Color and girls in science (Mensah & Jackson, 2018). If we want to prepare justice-oriented science teachers, it will be important to consider this endeavor from a program and systems perspective.

Felix: Science and Teaching as Socially-constructed

Felix shifted both his framework of science and of teaching toward ideas aligned with justice-oriented science teaching. He reflected on and questioned his ideas of science as a way for people to uncover truths about the world and shifted to a conception of science as socially- and culturally-constructed. His shift in his science framework aligned with his shift in his teaching framework from a focus on creating the one best Chemistry curriculum for all students to considering the importance of student voice and co-construction of knowledge, goals, and

norms with students. These shifts in frameworks were tied to Felix's idea of himself as a questioner, what it meant to be a scientist, as well as his experiences in a Chemistry Education lab which focused on a constructivist view of learning. There were as many ways to learn as there were people, as learning was shaped by individual experiences and contexts. This meant that particular ideas of what it meant to be successful in school and science could be questioned and expanded. Felix found that recognizing these differences was more inclusive for himself and for his future students. Felix's shifted frameworks supported a foundation of rightful presence for everyone in the classroom and the value of actively and carefully incorporating multiple frameworks of science into science education.

FINDINGS FOR RESEARCH QUESTION 2: METHODS CLASS OPPORTUNITIES

There were several learning opportunities in Methods Class that were designed to support PSTs in deepening their understanding of their own and others' frameworks of science and teaching. These learning opportunities were designed to support one or more of the three parts of operationalizing Gee's (2016) Frameworks Discourse Analysis (FDA) with PSTs. There parts were: 1) identifying their own ideas of science and teaching (articulating frameworks), 2) questioning and reflecting on why they held the ideas they did and why others might hold similar or different ideas (critically discussing frameworks), and 3) considering what these ideas meant for how they wanted to teach science (reflecting on and revising frameworks). Including all of these types of activities was important as PSTs were supported in making explicit what they thought about science and teaching and why, critically engaging with multiple ways to think about science and teaching, and reflecting on those multiple ways so as to revise their own ideas and reasoning.

In the next sections, I highlight the activities that PSTs identified as most helpful for them in each of these three categories and/or the activities connected to shifts (e.g., adjusting, questioning, reinforcing) in PST ideas and explanations of science and teaching. I first provide an overview of the activities related to each part of FDA as addressed in Methods Class. I then take a deeper dive into the types of activities designed to support part 2 (critically discussing frameworks) as the primary learning opportunity that supported steps 1 and 3 (the Science Story and Weekly Reflection Journal) has been discussed in the previous findings chapter focused on PST frameworks. Instead, in this chapter, I take a closer look at the types of activities that supported PSTs in considering multiple frameworks and how these might relate to their own

ideas of science and teaching. In short, I focus on the activities that provided PSTs with the content to reflect on and use to revise their Science Story.

Articulating Frameworks

To support PSTs in identifying and articulating their own ideas/frameworks of science and teaching, we (instructors) utilized the Science Story and Weekly Reflection Journal. These assignments provided spaces for PSTs to document their current ideas and how they were thinking about the experiences, values, and assumptions that were underlying these ideas. All eight PSTs interviewed named the Science Story as an important assignment for helping them think through their own ideas of science and teaching. Several PSTs also noted that the Weekly Reflection Journal was helpful for them to process their ideas, especially in response to topics and discussions in class. Three focal PSTs' ideas of science and teaching and how they questioned and reflected on these ideas are documented in the previous Findings Chapter.

Critically Discussing Frameworks

We designed Methods Class to support PSTs in questioning and reflecting on their own ideas of science and teaching, as well as those of others. We designed activities for this purpose across three themes: 1) science as cultural, 2) expanding what counts as a successful science student, and 3) sociopolitical issues in science and teaching. Activities for each theme were threaded throughout Methods Class and often overlapped with one another. In this section, I provide select examples of activities relevant to each theme, explain how each activity supported the relevant theme, and provide examples of how focal PSTs engaged in each activity and expressed this engagement in their Science Story and/or Weekly Reflection Journal entries.

Reflecting On and Revising Frameworks

Reflection in multiple forms was built into every part of Methods Class. We provided opportunities to reflect on the ways our class was being conducted (e.g., feedback surveys), how each PST was working toward co-constructed class goals (e.g., mid- and end-of-semester assessment rubrics and discussions), how PSTs and their group mates were implementing teaching practices toward particular goals/purposes (e.g., Critical Friends Groups and Reflection write-ups after peer teaching), how they were thinking about ideas brought up in class and their relation to science and teaching (e.g., Weekly Reflection Journal prompts/entries). We also provided time and space to reflect more directly on the Science Story and how ideas and experiences during the semester were related to each PST's Science Story and what that meant for their ideas of science and teaching and the supports for those ideas. As they are more directly tied to expressing frameworks, I focus on the Science Story and Weekly Reflection Journal in this study, but reflecting and revising ideas was a core theme across all parts of Methods Class. A key part of the Science Story and Weekly Reflection Journal was that they were living artifacts across both semesters of Methods Class. They were intended to be added to and/or adjusted. They were spaces for questioning and trying out new or different ideas. The Science Story provided a way for PSTs to document their ideas about science and teaching, what supported those ideas, what questions they had, and adjust those ideas based on different experiences and perspectives they had considered both in and out of Methods Class. Through the Science Story editions, PSTs had a way to reflect on ideas and experiences from Methods Class and how those ideas and experiences might fit within their frameworks of science and teaching.

Types of Activities that Supported Critical Discussion of Frameworks

In this section, I discuss the types of activities that supported PSTs in critically questioning and discussing their ideas of science and/or teaching, the values, assumptions, and experiences underlying those ideas, and the affordances and constraints of their familiar ideas and different ideas presented in class. These activities fall into one of three categories: 1) science as cultural, 2) expanding what counts as a successful science student, and 3) sociopolitical issues in science and teaching. The science as cultural activities were designed to support PSTs in reconsidering the common notion that the science learned in school is neutral (i.e., acultural and acontextual). The "expanding what counts as a successful science student" activities were designed to support PSTs in considering what their and students' goals were for science class and the ways teacher practices communicate what science is and what it means to be successful in science in more expansive or restricting ways. The sociopolitical issues in science and teaching activities were meant to make explicit the ways science and teaching are political and shaped by social events and to provide strategies for acknowledging social and political structures and systems in science and school in ways that promoted critical thinking rather than reinforcement of stereotypes. All activities in all categories were intended to provide multiple ways to think about science and/or teaching and question why we might think about science/teaching in particular ways and what the affordances and constraints of those ideas might be and for whom.

Science as Cultural

An important step in supporting PSTs in examining how they had developed their own framework of science was working with the idea of science as shaped by culture. Considering and understanding the ways that culture has and continues to shape how science is done and the

scientific knowledge generated was intended to support PSTs in recognizing the ways their own culture had shaped the ways they thought about science, that there were multiple ways to think about science, and that considering and incorporating multiple ways of doing science could strengthen both science and their own understanding of the world. In Methods Class, we incorporated multiple activities to expose PSTs to examples of ways science has been shaped by culture. In this section, I describe three sample activities, the ways they illustrated the cultural nature of science, and the ways PSTs, including my three focal PSTs, took up these ideas.

Asters and Goldenrod and What is Natural? Activities

In the following two activities, PSTs' ideas of what counts as science and who decides were surfaced. In the first activity, all PSTs shared ideas of people needing to be more inclusive in terms of what counts as science, perhaps because they were critiquing a particular person's clearly narrow perspective of what counted as science, rather than a systemic issue of exclusion. In the second activity, PSTs' personal assumptions about how to interpret the world were surfaced. As they reflected on this activity in their Weekly Reflection Journals, Alice expressed a problem she had with a perspective different from her own and relied on a dictionary definition to support her position without considering cultural influences. Willow stated her perspective and explicitly noted that this was one perspective of many, these perspectives were cultural and all were valid. Felix took up the idea of science as collaborative rather than authoritative which came up in the discussion of the first activity and expanded on this with his reflection on the second activity by stating that everything, including science was shaped by people and their individual experiences. Alice used this opportunity to reinforce her framework of science as absolute truths which were stated in dictionaries and textbooks. Willow used this activity as an example of how ideas were culturally shaped and multiple ways of thinking should be respected.

Felix used this activity to reconsider his initial idea of science as uncovering truths by reinforcing his idea of all knowledge as individually constructed. In the following two sections, I describe the activities and the PST responses to these activities in relation to their frameworks of science.

Asters and Goldenrod Chapter Reading and Discussion. Over halfway through the Fall Semester of Methods Class, we (instructors) introduced a reading that brought up ideas of culture in science, specifically a "western" view of science and an "indigenous" view of the world. We introduced this reading after having worked through several activities to support PSTs in articulating and sharing their ideas about what science was and what "good" science education was like. This reading was one chapter from Robin Wall Kimmerer's book, Braiding Sweetgrass. Kimmerer was a Potawatomi woman and held a Ph.D. in Botany. In her book, she shared stories of her life, in particular ways she navigated what she called science and traditional knowledge or indigenous ways of knowing.

In this particular chapter, Asters and Goldenrod, Kimmerer shared her story of starting a university degree in botany and having her knowledge of plants dismissed by the person registering her for classes because it did not align with his view of what counted as science. Kimmerer identified this rejection of her ways of knowing as similar to what happened to her grandfather at school "when he was ordered to leave everything – language, culture, family – behind. The professor made me doubt where I came from, what I knew, and claimed that his was the *right* way to think." (Kimmerer, 2013, p. 41). In the rest of the chapter, Kimmerer described her experience with science in the university and how she learned to succeed in this kind of science which, "trained me to separate, to distinguish perception from physical reality, to atomize complexity into its smallest components, to honor the chain of evidence and logic, to

discern one thing from another, to savor the pleasure of precision," (Kimmerer, 2013, p. 43). Kimmerer appreciated and did well with this kind of science. She then described how she went to a lecture by a Navajo woman who shared her knowledge of all the plants in her valley, their relationships, "the stories held by those plants, their origin myths, how they got their names, and what they have to tell us. She spoke of beauty," (Kimmerer, 2013, p. 44). She described how she felt listening to this woman share her knowledge, "It was the beginning of my reclaiming that other way of knowing that I had helpless let science supplant. I felt like a malnourished refugee invited to a feast, the dishes scented with the herbs of home," (Kimmerer, 2013, p. 44). Kimmerer both appreciated science and recognized the value her traditional knowledge held. She ended the chapter with her perspective on science and traditional knowledge, saying, "We see the world more fully when we use both," (Kimmerer, 2013, p. 46). In this chapter, Kimmerer shared her perspectives on botany from a university science perspective and a traditional indigenous knowledge perspective. She saw value in both ways of knowing and shared an experience in which one way of knowing was treated as the only right way of knowing.

As instructors, we asked PSTs to read this chapter as a way to introduce an idea that there are multiple ways of thinking about the world and that these ways are tied to different cultures. The message was not that one was better than the other, but that by understanding and drawing from multiple ways of thinking about the world, we gain a fuller understanding of the world.

In class, we (instructors) asked PSTs to share their initial thoughts about the Asters and Goldenrod chapter in what we called "virtual stickies". This was a slide in our interactive shared class slides which had a prompt at the top and twenty-eight colored squares (representing sticky notes) that served as text boxes. Each PST could select a square and type their thoughts. We then asked PSTs to look over all the ideas on the virtual stickies slide and we had a whole class

discussion about the professor's assumptions about the relationship between school science and indigenous knowledge.

Virtual Stickies. In the virtual stickies, PSTs shared ideas related to what science was, the relationship between culture and science, and who decided what science was. Several PSTs brought up the question of why some questions would be considered scientific while others were not and who had the right to decide this. Several other PSTs noted that it was interesting that the same person could change their ideas of what science was in their lifetime and that this showed that "we too can adapt our perspectives" (Virtual Stickies, November 2, 2020). Across the class, responses seemed to accept that both ways of thinking about the world presented by the author were valid and interesting ways to do so and this called into question the idea that there was one correct way to do science. This idea was taken up in the subsequent whole class discussion.

Whole Class Discussion Notes. In the whole class discussion, PSTs started the discussion by sharing experiences they had had that helped them relate to the author. They shared how it felt when a person in authority told you that you were a scientist or when they decided for you that you could only do a very specific type of science. One PST brought up their experience in a sociology class focused on science and technology sharing that, "The way the advisor [in the chapter] is thinking about science is pretty problematic and pervasive in the education system. Forcing someone to specify into one specific science is very much against scientific thought. You're not promoting healthy and innovative questions in science." (Class Notes, November 2, 2020). This idea that science should be more open to multiple ways of thinking about and asking questions about the world was shared across several PSTs in both the whole class discussion and the virtual stickies. This idea led to a discussion about what science was and should be. One theme was that science required curiosity, whether it was taught that

way or not was different for different PSTs. One PST brought up the idea that there was an inherent contradiction in what science was and how people interact with science, saying, “One of the big things was curiosity. Science is supposed to be not authoritative. There is no one person who says what science is, but there’s also the idea that we rely on experts to prove what science is.” (Class Discussion Notes, November 2, 2020). The instructor, Timothy, called out this contradiction in the form of a question for the class, “Science is not authoritative; We rely on experts to ‘prove’ what science is; How do these conflicting ideas relate to science class? I’m willing to bet almost all of you have at least one class where someone is standing up front and saying, this is the science that matters in his specific field. Does that reflect science accurately?.... Are we doing a disservice to science to say that this is what you need to know about the world?” (Class Discussion Notes, November 2, 2020).

Felix. Felix referred to this class discussion in his Weekly Reflection Journal that week. He took up the idea that science should not be authoritative and he added what he thought science should be, which was collaborative. This idea came out of the discussion of who got to decide what counted as science and what did not in response to the story of a woman whose science idea was devalued by a person in a position of power at a university. This woman succeeded in taking up the sanctioned way of doing science and also found that in order to do so, she had given up another important way of knowing. Ultimately, she found that drawing from both ways of knowing was beneficial, but she had to figure this out on her own in spite of the ways her indigenous way of knowing was devalued in the university setting. Felix rejected this idea that an authority figure should determine what was and was not science and stated that science should be collaborative, welcoming the multiple ways of thinking of many people doing science together.

Alice. Alice focused her Weekly Reflection Journal entry on a different activity we did together that day, which made sense as Alice got into a heated discussion with another PST during this activity, which was the focus of her journal entry. I will discuss this activity next.

What is Natural? Activity. After discussing the value of multiple ways of knowing in science and questioning who got to decide what counted as science, we did another activity designed to surface PSTs' own particular ways of viewing the world. This activity was called "What is Natural?" after the primary question posed throughout the activity. In this activity, PSTs were presented with a series of images and after observing each image, were asked to share out what they thought was natural in that image. The first image is depicted below in Figure 3.

Figure 3. What is Natural? Image 1

As one might imagine, PSTs hesitantly called out several things they saw, such as trees, water, clouds, mountains. I say hesitantly because when the responses seem obvious, there is often suspicion that the question is a trick question. At the same time, this was not the first time we

(instructors) had asked PSTs to make observations in class with the intention of doing something further with those observations, so this was not an entirely new request.

After eliciting several responses about the first image, we (instructors) showed the second image and asked the same question, “What is natural?” The second image is below in Figure 4.

Figure 4. What is Natural? Image 2

PSTs called out responses such as trees. Some stated that the trees on the right were natural while the trees on the left were not. I asked them what the difference was between those trees and they shared that the ones on the left had been planted intentionally, so they were not natural. Considering these PSTs had been educated in the U.S., this response was expected. A common assumption was that natural meant anything not influenced by humans. The next images were chosen to explicitly raise this assumption behind the determination of what was natural and what was not. The images were of a cement dam first and then a beaver dam next. When asked what

was natural, PSTs identified the cement dam as unnatural for several reasons. When they saw the image of the beaver dam and decided that the beaver dam was natural, the only difference between the two was that one was made by humans and the other was made by a beaver. In this exercise, PSTs stated what they thought was obvious and then were led through a series of images designed to surface the foundational claim they were drawing from to make their statement about what they were seeing. This led to a whole class discussion about what it meant for something to be natural.

Whole Class Discussion on What is Natural. In this discussion, the first point that was surfaced was that something natural was part of nature and humans were not part of nature, so anything made by humans was not natural. A question was posed of, "Do you think that's because humans don't like being classified as animals?" and the response was, "Yes" Another PST stated that they thought this was a cultural view. Someone else raised the idea that this idea of humans as separate from nature was about having "mastery over nature" and that it was "problematic to say humans aren't part of nature because we've changed the way the world is". Another PST explicitly stated that this was a Christian perspective of humans having control over every animal in the world. Another PST agreed with the biblical interpretation, but stated that biologically humans were part of nature, but that even while saying that biologically humans were part of nature, they wanted to be careful to state that humans were more valuable than other species. At this point, another PST shared a different perspective that humans were not necessarily more valuable than other species and that "there are some humans I probably wouldn't save over my dog." At this point, Alice stated emphatically, "I think that's extremely problematic." (Class Discussion Notes, November 2, 2020). In this discussion, several different ways of seeing the world were surfaced. These ways of thinking about the world were typically

left implicit, but through this activity were made explicit. As PSTs encountered strongly held ideas that differed from their own, conflict arose. PSTs who earlier in the class had stated that different ways of thinking about the world were necessary for science, pushed back on ways of thinking asserted by their peers. Most of the PSTs were sharing a version of a view of the world that was grounded in Christian ideology of humans as apart from and superior to the rest of the world. The PSTs who brought up that humans were part of nature and that perhaps humans were not inherently superior to or more valuable than other creatures were positing a way of thinking more in line with Indigenous North American Peoples' ways of thinking in which humans are a part of nature and other species are human relatives.

In the Asters and Goldenrod Chapter, PSTs took in the author's two different ways of knowing and recognized the value in them. When confronted with a way of knowing that was different from and conflicted with their own, PSTs pushed back on their peers' perspectives and the conversation became heated and had to be cut off by instructors.

Alice. Alice strongly objected to the idea that humans were part of nature and that humans were not inherently more valuable than any other organism. She pushed back on her peer's assertion that they would probably save their dog over some humans. Later in her Weekly Reflection Journal entry, she restated her belief that natural meant of nature and she drew from an expert source to support her assertion:

> I like to use concrete definitions in cases like this, so I would define natural as it appears in a dictionary: "found in or produced by nature". This may imply that I think of science as a one-way, right-answer-only, type thing as well. In a lot of ways, I do think like this. I do think there are definite truths- in science and in life. (Alice, Weekly Reflection Journal, November 2, 2020)

In response to this activity, Alice went back to what she was familiar with, which was drawing from dictionary definitions to support her case. She reasserted her idea that there were definitive

truths and there was one right answer in science. This right answer was supported by a definition from a dictionary. Relying on what she saw as expert sources such as dictionaries and textbooks was a foundational part of Alice's framework of science and she drew from it in this instance when her view of the world was challenged. She also apologized for getting heated in class and said that she had a problem with people devaluing human life. Alice saw the challenge to the claim that humans were more valuable than other species as devaluing human life, as opposed to seeing humans as part of nature meaning that all life was valued, including human life.

Felix. After this activity, Felix stated his definition of what is natural in his journal entry, which was part of the intention of the activity; to support PSTs in reflecting on and explicitly articulating their own ideas they use to interpret and act in the world by surfacing values they may not have realized they were drawing on. In his Weekly Reflection Journal entry on November 2, 2020, in response to a question about the "What is Natural?" activity, Felix wrote:

> I do not know how my views on what makes something natural or something as science, but indirectly this shoulds that everybody can have different interpretations of words, phrases, questions, answers, books, art, movies, science. We all have individual experiences which shape how we interact with the world and interpret speech and actions. This only further provides evidence that we all have different knowledge, due to our individuality. (Felix, Weekly Reflection Journal, November 2, 2020)

Here, Felix acknowledges that different people can interpret things differently, including science and that individual people have different knowledge. This was a step away from thinking about science as uncovering truths as Felix acknowledged indirectly that there was not a truth to be uncovered, but rather multiple ways to interpret the world and develop knowledge based in individual differences. Felix does not address where these individual differences come from, but he acknowledges that they exist. This aligns with the shift in ideas Felix included in his Science Story edition. Between Science Stories 1 and 2, Felix shifted from stating explicitly that science

uncovers truths to adding the idea that “Science is informed by and created by society and culture scientists construct their own reality when interacting with data” and that “Science is not authoritative, it is collaborative,” (Felix, Science Story 2). In his framework of science, Felix was shifting from an idea of science as uncovering truths to an idea of science as created in and shaped by social and cultural contexts.

Willow. After the What is Natural? activity, Willow reflected on how she was thinking about what counted as natural, writing, “To me, natural is something that happens without human influence. Natural, to me, is a human-made concept to describe things that happen without us.” She stated how she was thinking about what this word meant and then immediately noted that this definition had implications for how she thought about humans and our position in the world, “I recognize that this positions humans outside of nature, and I don’t necessarily see humans as always being separate from nature, but if I had to give a specific definition for natural, I think this is the most broad definition I can think of.” Willow then stated, “I think ideas of what natural means is very culture specific, and I don’t think that other definitions of natural are wrong by any means.” (Willow, Weekly Reflection Journal, November 2, 2020). In this journal entry, Willow articulated her own idea of what “natural" meant, identified the particular implications or assumptions underlying her idea, and stated that this definition was cultural and that there were other definitions of natural that were also valid. She explicitly stated this in the next part of her journal entry, writing, “Honestly I think natural has tons of valid definitions. I don’t feel like mine is more correct than people who believe that natural is everything that can happen because humans are a part of nature. I feel like there are also probably other definitions, but these two seem to be the main ones we talked about in class today.” (Willow, Weekly Reflection Journal, November 2, 2020). Willow recognized that there were multiple definitions

of “natural” and that she did not think her definition was better than another definition, it was just her definition based in her culture.

This idea that at least some definitions were culturally based and that there could exist multiple valid definitions of terms, which held implications for how people thought about human beings’ place in the world aligned with Willow’s framework of science as a tool that could and should be adapted to support people’s analysis and understanding of the world. In Willow’s framework of science, people analyzed and explored the world and drew on their own experiences and ways of knowing to do so. Willow saw science as a tool that was versatile enough to be useful for people drawing from a variety of experiences and ways of knowing.

Four Framings in Science Reflection and Discussion. The three focal PSTs took up these examples of framings/frameworks in science in different ways. All three considered the examples and identified the framings/frameworks underlying the science. Alice described what she saw as the original framing and the new framing for each example and ultimately decided these examples did not provide clear enough evidence that people’s cultures influenced the products of science, so she rejected these examples and maintained her framework of science as absolute truth. Willow identified each underlying framing/framework by name, indicating familiarity with these framings/frameworks, which was consistent with her framework of science in which multiple cultural and social ways of understanding the world were valued. Felix immediately identified each example as demonstrating the ways that science was done in social and cultural contexts of the people doing the science and that this influenced the science itself, which aligned with and supported his shifting framework of science toward an idea of science as shaped by social and cultural contexts.

The Activity. In the Spring Semester of Methods Class, we (instructors) explicitly introduced the idea of framings/frameworks in science as a way to think about how culture was related to science. In this activity, we reintroduced the idea of "framing", which I refer to as "frameworks" in this study. We provided a brief definition/description of framings/frameworks as "a way of thinking connected to experiences and values". We shared a maps analogy drawn from Medin and Bang's (2014) book that illustrates how different people in different contexts with different purposes will notice and represent things differently, much like someone going on a road trip and someone going birdwatching would likely create or find useful two very different maps of the same area. The Roadtrippers and the birdwatchers would be employing different framings/frameworks to represent the same place based on different experiences and values. We included an explicit statement of why framing/frameworks matter that "Who you are shapes your way of thinking, which shapes your science". Then, we asked PSTs to individually read four scenarios, reflect on the framing used and why it mattered to the science and write their ideas as an entry in their Weekly Reflection Journal.

We provided four scenarios that each illustrated a different framework and the science shaped by that framework. The first described how a scientist guided by an Indigenous framing/framework developed innovative research methods when current common methods did not align with her framing/framework, the second discussed how sexism and patriarchy shaped the science around the process of fertilization, the third discussed how using heterosexuality as a baseline pushed evolutionary biology questions in a direction that was not useful, and the fourth called into question the framing/framework that harming non-human animals is acceptable in the name of science. We asked PSTs to begin by writing their thoughts on these scenarios in their Weekly Reflection Journal so that we, as instructors, could see what these initial thoughts were

and make sure that any harmful ideas that might be surfaced could be worked with outside the whole class setting so as not to perpetuate harmful stereotypes and ideas within the class. These scenarios also provided examples of the ways scientists' social and cultural contexts influenced the science that was done.

We then facilitated a whole class discussion about these four framings/frameworks and the science connected to them. PSTs shared the perspectives they noticed in the scenarios. Within this discussion, PSTs brought up the connection between framings/frameworks and culture as well as ethics and how this connects to what and how science is done. PSTs also brought up that there were multiple levels of framing/frameworks in this assignment, those of: the authors of the scenarios, the instructors who chose the scenarios, and the values/views of the scientists in the scenarios.

Alice. Alice demonstrated that she was willing to try out and think through ideas different from her initial ideas, even when those new ideas conflicted with her current ideas/framework.

In this activity, Alice documented what she identified as the "original framing" and the "new framing" of each example. She noted that in the first example, the science was "framed around care/respect for animals" and that this framing led to reconsideration of "potentially cruel practices". This particular method of doing science was informed by the scientist's framing of "care/respect for animals". This was the example Alice took up as a reasonable example of culture and framings/frameworks influencing science. The particular methods of doing research could shift based on scientists' cultural beliefs, but the results of that research would be the same regardless of method because science was about generating truths about the world. In this example, the buffalo DNA was the same and the conclusions the scientists drew about buffalo DNA were the same, only the method of gathering that DNA was different. This method did not

change the knowledge generated. This example aligned best with Alice's framework of science as made up of truths generated by experts.

In this activity, Alice identified the framing of the fertilization example as "less male-center[e]d" and that it "gives fertilization some credit to females" and that this "presents a new model for fertilization and places value on female roles" (Alice, Weekly Reflection Journal, February 1, 2021). In contrast, when Alice and I later spoke about framings/frameworks in science, she cited this fertilization example as one where she did not see enough evidence that the people studying fertilization believed in specific gender roles and had applied that to their observations and descriptions of the process of fertilization. It made sense to her that those scientists saw the sperm moving and the egg stationary and described the process in that way. This idea of scientists' framings/frameworks influencing the scientific knowledge they produced did not align with Alice's framework of science and this example did not provide strong enough evidence to shift the claims in her framework to include ideas of science as shaped by scientists and their cultural and social contexts. Alice tried out this idea and rejected it based on insufficient evidence.

Willow. Willow identified what she saw as the framing of each example. She first either copied and pasted the description or summarized the example and then noted the framing underlying each example. For the first example, she identified the framing as "respect for bison as living organisms. Indigenous science." For the second, her framing was "feminism", the third was "LGTBQ+" and the fourth was "respect for animals, religious views (reincarnation?)" (Willow, Weekly Reflection Journal, February 1, 2021). Willow identified each framing using a label/term that she already knew and associated with the examples. This indicated that these were already framings with which Willow was familiar. She recognized them and had a name to

label them with. This activity provided Willow with additional examples of these framings/frameworks with which she was familiar in the context of science. Willow readily took up these examples as evidence that supported her framework of science as a tool that should be adapted and usable for/by everyone.

Felix. Felix focused his writing about the four examples of framings/frameworks within science on identifying the ways those framings/frameworks related to science more broadly. Felix identified the information about Flo Gardipee as Native American as "possibly explain[ing] their motivations for the unique method of gathering DNA samples," (Felix, Weekly Reflection Journal, February 1, 2021) implying that being Native American was related to her methodological choices as a scientist, which was the point of that example. In response to the fertilization example, Felix wrote, "Stereotypical gender roles, which are ingrained in our culture, therefore are ingrained in the cultures of the people who historically participate in science, perpetuating gender roles. Framing the sexes and the role of a fundamental human experience is dependent on the person doing the framing, as the personal beliefs determine that framing," (Felix, Weekly Reflection Journal, February 1, 2021). Felix explained that these stereotypical gender roles were an example of an idea that was not just part of the culture he was part of, but was ingrained in that culture, which meant that these gender roles influenced the way this science was done and that the science reflected the stereotypical gender roles that these scientists accepted as normal/typical behavior. Felix expressed a similar thought, although in a condensed form, in response to the example of scientists basing their explanations of animal behavior on a heterosexual sex as the norm assumption, writing, "Science is a social enterprise, those values held by the 'people' doing science are ingrained in that 'science.'" (Felix, Weekly Reflection Journal, February 1, 2021). Felix took each of these examples as an instance of the

scientists' personal beliefs and culture shaping the science and used this to explicitly state that science was a social enterprise shaped by the people doing that science. This supported Felix's framework of science as he shifted from an idea of science as uncovering truths to science as constructed in social and cultural contexts.

Expanding What Counts as a Successful Science Student

Something we (instructors) thought was important for PSTs to consider was what PSTs thought it meant to be a successful science student. What were PSTs' goals for their students? What would their teaching practice look like to support students in working toward those goals? We (instructors) designed and implemented activities across Methods Class to support PSTs in considering, articulating, and questioning what they thought it meant to be a successful science student and what the teacher's role would be in supporting student success. In this section, I describe three activities, how they designed to support PSTs in considering and articulating what student success was and what the teacher's role was to support this success, and how each focal PST (Alice, Willow, and Felix) engaged with and applied their experiences with these activities to their frameworks of science and teaching. I begin with an activity intended to clarify what it meant to center student ideas in science education. Next, I describe an activity that was taken up three times over the course of Methods Class, in which PSTs read scenarios describing interactions between students and teachers with different framings/frameworks of science with the intention of supporting PSTs in considering the importance of recognizing multiple frameworks in their science classroom. Finally, I describe a set of activities intended to support PSTs in articulating and questioning how they defined "intelligence" in the science classroom.

Sensemaking and Ambitious Science Teaching

We (instructors) prompted PSTs to reflect on how they were thinking about sensemaking in science education. Alice, Willow, and Felix each reflected on sensemaking differently and in ways that made sense within their frameworks of science and teaching. Alice discussed leading students down the correct path of sensemaking. Willow focused on the importance of sensemaking as more useful activity than memorizing given information. Felix focused on the process of sensemaking and how this supported students in becoming scientists.

Using a Sensemaking Analysis Tool. One of the things we (instructors) noticed during the first 20-minute Microteach activity was that PSTs were trying to enact the focal Ambitious Science Teaching (AST) practice of eliciting student ideas while doing what they assumed a teacher would do in a full lesson. Based on our observations of the Microteaches and PSTs' reflections on the assignment, we (instructors) realized that PSTs were struggling, at least in part, because they did not have a clear understanding of the full cycle of AST, and more importantly, we (instructors) had not been clear enough about the reasoning behind the AST cycle and associated practices. As we (instructors) understood AST, the primary focus of the framework was to support student sensemaking through examination and explanation of phenomena. A key part of AST was its focus on supporting students in working with and on their own and their peers' ideas toward generating an evidence-based explanation of a phenomenon. AST focused on supporting students in "constructing knowledge about the world around them" (Russ, 2014, P. 394). Before we could expect PSTs to take up AST practices, we needed to support them in thinking about their purpose of science teaching and where the role of student sensemaking fit. Then PSTs could make informed decisions about which teaching practices best supported what they thought students should be doing in the science classroom.

We (instructors) shared some ideas of how people think about the purpose of science education, specifically drawn from Russ' (2014) article discussing what she called an epistemology of science and an epistemology for science. We shared a common way of thinking about school science, which is to support students in doing what professional scientists do because that is what professional scientists do. For example, if professional scientists use microscopes, students should be trained in how to use a microscope. We then shared two quotes from Russ' (2014) article, "If we believe that the purpose of science education is the train people to understand the discipline of professional science, to understand the claims that are made within that discipline, and to evaluate the appropriateness of those claims, then encouraging learners to adopt, enact, or practice the epistemology of science is critical," (p. 394) and "If on the other hand, we believe that science education serves the goal of helping learners become better at constructing knowledge about the world around them, then explicit ties to the disciplinary practices of science become less important," (p. 394). We (instructors) asked PSTs to consider whether the purpose of science education was to teach students to imitate professional scientists by taking up the practices of professional scientists or if the purpose of science education was to support students in constructing knowledge about the world around them by selecting the practices that best help them construct that knowledge. In other words, did we, as educators, want to teach students to enact the practices of professional scientists for the sake of enacting those practices or did we want to support students in enacting practices that best helped them construct knowledge of the world, which was the ultimate goal of science and professional scientists? After posing this question, we asked PSTs to analyze an excerpt of a video of a science lesson focused on supporting students in sharing observations about a phenomenon they were observing. We provided PSTs with a tool for analyzing the sensemaking

happening in the video and asked them to try it out in class and to share their thoughts aloud. Then, we asked PSTs to select an excerpt of their own video of their first Microteach and analyze that excerpt using the same tool. This tool was designed to guide PSTs in paying attention to what the teacher was doing, what ideas were shared, who interacted with these ideas, and in what ways, and finally, how science was presented, whose ideas mattered, and how the teacher's practice supported student sensemaking, as seen in Figure 5 below.

Figure 5. Sensemaking Analysis Tool

Sensemaking Analysis

<table>
<tr><th>Things to Consider</th><th colspan="3">Your Analytic Note</th></tr>
<tr><td>Practice</td><td colspan="3">What is the teacher doing?</td></tr>
<tr><td>Positioning of Ideas</td><td>Ideas
[What ideas are present? How are ideas being represented? What is done with these ideas?]</td><td>Students and Ideas
[What are students doing relative to the ideas?]</td><td>Teacher and Ideas
[What is the teacher doing relative to the ideas?]</td></tr>
<tr><td rowspan="2">Outcomes</td><td>How science is presented in this practice:</td><td colspan="2">Whose ideas mattered:</td></tr>
<tr><td colspan="3">How the practice supported students' sensemaking:</td></tr>
</table>

In response to the video excerpt, and using the provided tool, PSTs shared that the ideas in the class came from "students' prior knowledge", "real life experiences", and "looking at

materials on the table" (Class Slides, October 12, 2020, Slide13). PSTs also shared that they noticed that students in the video "built on each others' ideas a lot", "started to use language other students used", "engaged with ideas as they discussed with teacher by clarifying ideas as the teacher asked questions" (Class Slides, October 12, 2020, Slide 13). PSTs shared that the teacher "asks probing questions", "Does not say whether students are right or wrong", "revoiced student ideas", "directed where students' thoughts could fit in by pointing to questions on the worksheet", and asked students to provide evidence" (Class Slides, October 12, 2020, Slide 13). PSTs noted that in this excerpt, science was presented as "observational and hands-on", "science followed patterns and was logical" as the teacher facilitated a "discussion about plants making own food, we need good, then asked students what about fungi, the idea of all needing nutrients indicates a logical argument" (Class notes, October 12, 2020, Slide 13). PSTs also noted that they did not see a "clear motivation for asking for observations," which "made it seem that science is about observing, so that's what we'll do," (Class Slides, October 12, 2020, Slide 13). PSTs questioned why students in the video were being asked to make the observations about the moldy strawberries in a bag. PSTs were looking for a purpose for the activity beyond simply sharing observations. They wanted to know what this lesson excerpt was connected or leading to.

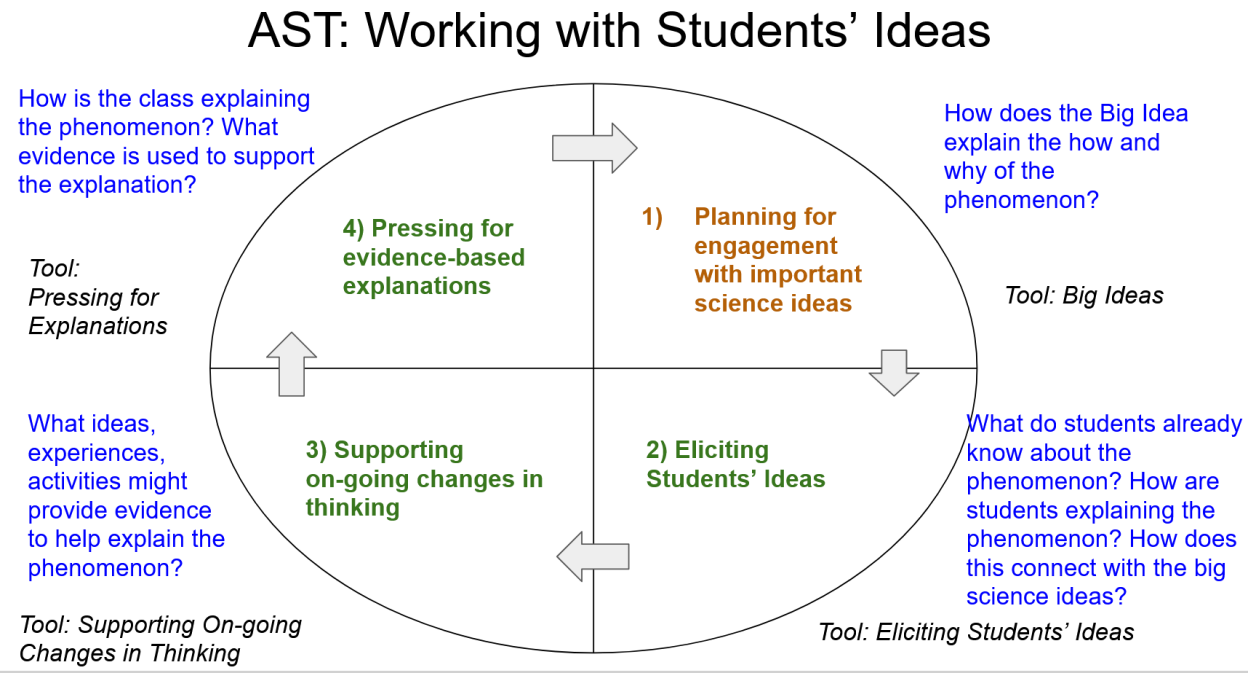
PSTs also questioned whether all ideas were valued in this lesson as the activity shown was structured around group work. PSTs were concerned that "the social structure within the school and group add on to whether your ideas are seen or valued/supported/listened to" (Class Slides, October 12, Slide 14). They saw value in group work, but wanted to know who created the groups and expressed that "norms within groups need to be well-defined with accountability for norms carried throughout the year" (Class Slides, October 12, 2020, Slide 14). PSTs were considering factors that could contribute to whose ideas were shared and taken up within small

groups and in the whole class discussion. They also provided an idea for how to create groups that would support all ideas in being heard and valued. PSTs shared the benefits of group work in this science class when they discussed the ways student sensemaking was supported in this lesson, sharing that, “if the goal is to have students place ideas in their conceptual framework, the idea of having groups allows student to use other students’ ideas as resources,” (Class Slides, October 12, 2020, Slide 14). PSTs noted that working in groups could serve to silence some students’ ideas if norms for sharing ideas were not well established and maintained and that working in groups could provide useful resources for thinking through the phenomenon in class and considering how different explanations fit in each students’ conceptual framework by having opportunities to consider group members’ ways of thinking about the phenomenon. Along the same lines, PSTs noted that this activity “allowed students to try on different explanations and see if they made sense,” by “listing off a bunch of ideas they get to see what makes sense or why it doesn't make sense, then come to a conclusion” (Class Slides, October 12, 2020, Slide 14). PSTs noted that not only could students discuss ideas within their group, but that the whole class discussion provided an opportunity to share out and think through multiple ideas and how well they described or explained the phenomenon. PSTs further noted that the, “teacher didn’t say if students’ ideas were right or wrong, [which] contributed to students making sense of their observations. Students arrive at their own conclusion to some extent,” (Class Slides, October 12, 2020, Slide 14).

Using this Sensemaking Analysis Tool to guide observations of a video excerpt of a lesson, supported PSTs in focusing on what ideas were present in the class, how ideas were worked with and by whom, and what kinds of messages were sent to students about what it meant to do science.

Connecting Sensemaking to the AST Framework. After analyzing the video excerpt for which ideas were present, who was engaging with these ideas and how, and what this meant for how science was represented in the classroom and how this supported student sensemaking, we (instructors) shared an overview of how we thought about the Ambitious Science Teaching (AST) framework. We shared an image of the AST unit cycle with a supporting question for each section and the tool we drew from to plan to enact each section. This image can be seen in Figure 6 below.

Figure 6. Instructors' Overview of Ambitious Science Teaching Framework



In this image, we noted what we saw as the main point of the AST Framework, to work with students' ideas in service of supporting student sensemaking about a phenomenon. The unit cycle began with planning for engagement with important science ideas, which we (instructors) thought teachers could think about in terms of answering the question for themselves, "How does the Big Idea explain the how and why of the phenomenon?" This was the preparation the teacher

would do to create the unit. They would decide what big science idea they would focus on and select a phenomenon which was explained by that big science idea. The teacher would have to be very clear on exactly how that big science idea explained the phenomenon in order to plan the unit. Once the phenomenon was selected and the teacher had a detailed understanding of how the phenomenon was explained by the big science idea, the next phase of the unit could begin, which was eliciting students' ideas. In this section, we were interested in "what do students already know about the phenomenon?", "How are students explaining the phenomenon?", and "How does this connect with the big science ideas?" In this section, teachers elicit students' ideas because students already have ideas about how the world works and those are valuable resources to build on together as a class. The next step was to support on-going changes in thinking. In this section, the teacher would look at the ideas that had been elicited and ask, "What ideas, experiences, activities might provide evidence to help explain the phenomenon?" In other words, based on the ideas students already shared, which ideas could be reinforced, which could be thought about differently through examination of new evidence? This was the part of the unit in which the teacher would bring in activities to push students to think more deeply and expansively about the phenomenon and how it worked. Finally, the teacher would press for evidence-based explanations. After students had shared their initial ideas, engaged in activities to question, reinforce, or adjust their initial ideas based on evidence, students would create an explanation for the phenomenon based on all the evidence generated and interpreted in the previous activities.

Providing this overview for PSTs was important because while they had experienced a shortened version of an entire AST unit earlier in the Fall Semester, they had not been familiar enough with the AST Framework to connect particular parts of that unit with what they might do

in their own teaching and with the AST Framework itself. We (instructors) had noticed this in the first Microteach when PSTs thought we were treating the Eliciting Students' Ideas practice as the only teaching practice, rather than as a stage in a unit.

Focusing on what was happening with ideas in a classroom and how the AST Framework provided a way to work with students' ideas to collectively build an evidence-based explanation for a phenomenon was important for supporting PSTs in explicitly thinking about what their role and their students' roles would be in their classroom and what this meant their students would learn about what it meant to do science. This was a step toward focusing on student ideas as at least as important in the classroom as the canonical science ideas with which PSTs were familiar.

Alice. Alice wrote in her Weekly Reflection Journal, "I think it is important to lead students down a path of sensemaking. When I come to conclusions on my own, I am more likely to understand a concept. I also think humans naturally use sensemaking every day when encountering unknowns," (October 15, 2020). Alice saw the value in supporting students in figuring things out for themselves as this was more useful for her when working to understand a concept. She saw her role as teacher as one of "lead[ing] students down a path of sensemaking" so the teacher knew the way to make sense of a concept and would show students how to do this for themselves. There was a proper way to make sense of concepts and the teacher knew what that proper way was.

Alice expanded more on her idea of sensemaking in science later in her journal entry, "I believe in definite truth. While people may perceive situations differently, there is still absolute truth. I also think that as educators, we have a responsibility to help students understand truth in science. There are truths that scientists agree are factual because of long periods of study, experimentation, and in-depth understanding. Helping students come to understand these known

concepts, scientific terms, and phenomena is essential to our role," (October 15, 2020). For Alice, sensemaking was important and so was the idea of absolute truth. People could have different perceptions of something, but those perceptions did not change what the truth was. This cornerstone of Alice's science framework was incredibly important for how she engaged with ideas of sensemaking in science education. Students could and should make sense of things for themselves and teachers had an obligation to connect students with the concepts that professional scientists had figured out through study and experimentation.

Alice believed strongly in the importance and value of the scientific body of knowledge with which she was familiar thanks to her own education in science. This body of knowledge was incredibly useful and connecting her students to this knowledge was a key part of her role as a teacher. Alice wrote about her thinking about student lives and experiences, "While it is useful to connect science to students' lives, understand their prior knowledge, and make sense of science, we have a moral and ethical obligation to teach them science from a factual point of view. I do not think conversations regarding 'what is truth' is useful for teaching or learning science," (Alice, Weekly Reflection Journal, October 15, 2020). Alice wrote about student experiences and ideas as separate and different from "a factual point of view".

The way we discussed student ideas and science ideas in Methods Class supported Alice in thinking about student ideas as necessarily different from science ideas. Alice knew the science ideas with which she was familiar had value and had been peer-reviewed by professional scientists. The ideas of students, at this point, were purely hypothetical. Alice questioned the value of focusing on possible student ideas at the expense of treating canonical science ideas with the respect they deserved based on the rigor of the process that produced these ideas. Student ideas and canonical science ideas were discussed in opposition to one another. For Alice,

if one set of ideas needed to be prioritized over the other, the canonical science ideas, which represented truth, were the obvious choice.

Willow. Willow's written reflection on sensemaking was short and focused on what kinds of thinking would best support students in making sense of phenomena. Willow stated that, "I feel like sensemaking very much happens in the student's brain. I think that we as teachers guide sensemaking. However, to actually make sense of a phenomenon, it requires active thinking and making connections on behalf of the student. I think that sensemaking is a more active process than just memorizing things," (October 15, 2020). Willow thought about sensemaking as something the student did for themself, but that the teacher could guide. This was similar to Alice's idea of teachers "lead[ing] students down a path of sensemaking" (Alice, Weekly Reflection Journal, October 15, 2020). Willow was focused more on the idea of students thinking actively about a phenomenon and making connections for themself and that this was a more active process than memorization.

Willow focused more on the process of students thinking and making connections about phenomena and how this compared to memorization, which made sense as Willow compared this idea of focusing on student sensemaking to her own science education in which memorization was praised as the primary way to learn science. Willow was not concerned about whether student ideas or experiences were aligned with canonical science knowledge the way Alice was. Instead, Willow was thinking about the benefits of students engaging in sensemaking to make sense of phenomena rather than simply memorizing the way phenomena worked. Alice was concerned with students learning the correct information, while Willow was focused more on the process of learning as she compared this focus on sensemaking to her own experience with memorization.

Felix. Like Willow, in his Weekly Reflection Journal entry, Felix was more focused on the process of sensemaking than the particular knowledge that students would be taking up. Felix began by defining sensemaking as "the process of changing your conceptual framework to fit a new resource inside your current/prior knowledge…. Sense-making is therefore learning, and learning is sense making," (October 15, 2020). Felix considered sensemaking to be synonymous with learning. He further wrote that, "in science education, my goal is for students to learn. Learn what? I do not know. Science, science epistemology, no. Sensemaking skills, perhaps," (October 15, 2020). Felix addressed the idea of a particular science or way of knowing in science and rejected this as what he wanted his students to learn. Instead, Felix proposed that perhaps he wanted his students to learn sensemaking skills. He wanted them to learn skills for learning or skills for "adding new knowledge to your conceptual framework" (Felix, Weekly Reflection Journal, October 15, 2020). Felix was not concerned with the particular concepts that students would learn. He was focused more on the process of learning that students would take up and engage in his classroom. This aligned with Felix's broader idea of knowledge as being personal and created by each individual. Felix was not concerned with the particular science content students would take up, but with students' skills in adding knowledge to their conceptual framework.

Felix placed himself squarely in the epistemology for science side of things as defined by Russ (2014), whereas Alice placed herself squarely in the epistemology of science side of things. Willow seemed to learn more toward epistemology for science, but did not explicitly address whether specific science practices should be taken up or for what purpose.

Focal Lenses: Culture, Identity, and Success/Intelligence

In the Spring Semester of Methods Class, we (instructors) considered how PSTs had been discussing ideas of what it meant to be a teacher and what that meant for their expectations for students. We realized that there were several lenses that we thought would support PSTs in questioning and analyzing their ideas about what it meant to teach and what they expected from students. These lenses were culture, identity, and success/intelligence. We already had a theme of science as cultural in our class and we thought that making this lens of culture more explicit would support PSTs in considering their own culture, their students' cultures, classroom cultures, and science cultures and in doing so, PSTs might deepen their understanding of themselves, their students, and how PSTs were thinking about what it meant to teach science and why. Similarly, we thought that if we could support PSTs in explicitly identifying their own and others' identities, the identities made possible by particular classroom structures and cultures, this could better support PSTs in articulating and questioning and deepening their understanding of their own and others' frameworks of teaching and science. Finally, we recognized that much of the ways that PSTs talked about teaching was centered around what it meant to be a smart or successful student and a successful teacher. We wanted to support PSTs in articulating and questioning how they were thinking about what it meant to be smart and successful, particularly in science class, and what that meant for them as teachers and for their students.

We started the Spring Semester of Methods Class with an introduction of these focal lenses and asked PSTs to define each concept for themself. Then, we designed activities intended to support PSTs in engaging with multiple definitions of each concept/lens and considering how that concept applied to their ideas of teaching. Different PSTs gravitated toward different concepts. In this section, I describe a set of activities designed to focus on each concept and

explain how one focal PST took up that particular concept. Alice focused on culture, Willow focused on identities, and Felix focused on intelligence. All three PSTs engaged with all the concepts, but I have selected one concept for each of the three focal PSTs as that concept was strongly connected to their frameworks of science and/or teaching.

Intelligence. In this set of activities focused on the concept of intelligence, we (instructors) designed these activities to provide PSTs with a way to articulate how they were thinking about intelligence, discuss their ideas of intelligence with their peers, and reflect on the ways intelligence is socially constructed in the classroom. We had begun by asking PSTs to individually write their definition of intelligence in a Weekly Reflection Journal entry. We then asked PSTs to work in small groups to create a model of intelligence, then do a virtual gallery walk of the group models. Finally, we showed a video which summarized a study on two fourth-grade classrooms in which the identity of "smart science student" was differently constructed in each classroom and connected with the ways students in each class identified who was and was not a "smart science student".

Whole Class Discussion of "Success" and Modeling "Intelligence". We, as instructors, had asked PSTs to write in a Weekly Reflection Journal entry at the beginning of the Spring Semester definitions of what they thought identity, culture, success, and intelligence were. For this activity, we (instructors) read through PST definitions of success and intelligence. The responses about success were very similar across PSTs and primarily concerned setting and achieving some form of goal. We created a shared class list of PST-identified aspects of success, shared this with PSTs in class and facilitated a short conversation about these class trends and how different people and societies may define success differently, how different people may even have the same goals, but different motivations for those goals and what does that mean for

how we view success in classrooms as teachers and students. After this discussion, we shifted to small group work related to how we define intelligence as the PST responses in their journal entries were more varied than the success responses. PSTs worked in their Macroteaching groups (each group created their own team name: Body Builders, BioBuddies, Dirt Eaters, Guardians of the Solar System) to create a model that represented intelligence. The guiding question for this model was "What is going on with intelligence?" This question was intentionally left broad and did not focus solely on a definition of intelligence, but was meant to invite multiple ideas about how PSTs were thinking about intelligence. We asked each group to include "parts of intelligence", "outcomes of intelligence", and "context of intelligence" to indicate further that groups should go beyond a definition of intelligence to think about outcomes and context. Each group created a model using a digital whiteboard program, took a screenshot of their model and copied and pasted it on their group's slide in the shared class slides. On each slide, we also included four squares, each with a different color, and labeled with each group's name. These squares were used as spaces for groups to write feedback during the virtual gallery walk of the intelligence models. In this way, each group interacted with each model.

Intelligence Models. In three of the four models, intelligence is associated with or defined as doing something with knowledge ("How much you know; how well you apply what you know. Applying knowledge from many sources to a particular situation according to one's particular goals." (Class Slides, Jan. 28, 2021, Slide 40: Body Builders Model) "ability to obtain new knowledge" (Class Slides, Jan. 28, 2021, Slide 41: BioBuddies Model) and "knowing and applying information" "More than facts and trivia" "Context for and understanding behind knowledge" "Being able to make knowledge and make connections amongst it" (Class Slides, Jan, 28, 2021, Slide 43: Guardians of the Solar System Model)). In the Dirt Eaters' model,

intelligence is not explicitly defined, but different forms of intelligence are listed, similar to how the Body Builders group listed types of intelligence, many of which align with Howard Gardner's eight types of intelligence (e.g., spatial, musical, logical/mathematical). (We did not provide any reference to Gardner's work, so this was drawn from resources from outside our Methods Class.)

In the Dirt Eaters Model, the idea of intelligence as being tied to perception based on context and that different forms of intelligence may be valued differently by society was included. This model also included an idea about intelligence as being located in the individual's brain and that, because of this, it is impossible to fully know another person's intelligence, but there is still the potential to label someone as smart or not smart, which is problematic. The Body Builders group indicated that they had a discussion about how people's perception of intelligence may differ from others' perceptions of their intelligence and then they made note that they would add this idea to their own model.

Video: "Who gets to be a 'Smart Science Student'?". After the gallery walk of models representing intelligence, we showed a short (~4 minute) video created by a colleague to represent a journal article by Carlone, Haun-Frank, and Webb (2011) that shared a comparative ethnographic study of two fourth-grade science classrooms and the differences in the ways students identified "smart science students" and the teaching practices that supported these different identities. In the video, we are introduced to two fourth-grade teachers and their classes. Each teacher has a reputation as a strong science teacher. Students participate actively and do well in class and on assessments, but when asked who are the smart science students in your class, the answers in the two classes were different. In the video, we learn how each classroom community defines "smart science student" differently, this is connected to the norms established

and reinforced by the teacher, and this influences who in the classroom sees themself as a "smart science student". This identity of "smart science student" is socially-constructed and influenced by teacher-established and reinforced norms. In particular, we learn that Mrs. Sparrow's focus on turn-taking meant dominant and more assertive students spent more time with resources and got more recognition for science ideas in the classroom. Students in this class identified "smart science students" as those who knew facts, answered the teacher's questions correctly, and did science at home. Only four of the fifteen students identified themselves as smart science students and five (all females of Color) immediately stated that they did not share any of the characteristics of "smart science students".

In contrast, in Mrs. Wolfe's classroom, she established norms of sharing scientific ideas and solving problems together. She modeled and explicitly discussed what this would look and sound like. She asked students to explain groupmates' ideas, consistently redirected students toward their partners, helped students share observations, build on others' ideas, and develop new questions and observations together. In this classroom, students identified "smart science students" as those who asked good questions, were good observers, were good group members, and kept trying even when they were wrong. All eighteen students identified themselves as smart science students.

This video introduced PSTs to ideas of identities as socially constructed, of classroom norms as playing a role in shaping identities within the classroom, and how these identities and norms can influence students' relationships with science.

Felix. Felix started off with the idea of intelligence as a social construct, as indicated in his Weekly Reflection Journal entry at the beginning of the Spring Semester, "Intelligence is… a social construct that people may have and it varies according to the value it places in that

society." (Felix, Weekly Reflection Journal, January 21, 2021). Felix further described how he thought of intelligence, writing, "I would argue that there is no one intelligence, but multiple forms of intelligence, such as spatial, emotional, logical/mathematical, interpersonal, intrapersonal, existential, linguistic, musical forms of intelligence." (Felix, Weekly Reflection Journal, January 21, 2021). Felix drew on the idea of multiple intelligences, which is commonly taught in education programs. He then wrote that not all of these intelligences were treated equally, "Often in society high value is placed only on a select few of these forms of intelligence according to their [perceived] value in society, such as logical or linguistic. I believe this is why science is perceived as a thing for highly intelligent people as it involves the majority of these forms of intelligence." (Felix, Weekly Reflection Journal, January 21, 2021). In this initial definition of intelligence, while Felix noted that intelligence was a social construct, he also thought of different disciplines, such as science, as relying heavily on particular intelligences, specifically logical and linguistic intelligences.

As Felix explained in his third edition of his Science Story, he did not see himself as a scientist because of his linguistic difficulties. Felix articulated his idea that there existed multiple intelligences and science relied on two particular intelligences, logical and linguistic. Felix could then identify that as he saw himself as struggling with linguistic intelligence, it was difficult to see himself as a scientist. He later questioned how intelligences were determined, in particular linguistic intelligence. This supported Felix in questioning the construct of intelligence itself and who got to decide what counted as intelligence. He focused, in particular, on linguistics and what counted as scientific language, in particular in his analysis of his Macroteach summative assessment. In his reflection on his Macroteach and the discussion after his Macroteach which he had with his peers (who had participated in the Macroteach as students), Felix noted that when

he was analyzing his students' work, he had been making assumptions about the kind of language he expected:

> I began to realize as we discussed that I had been projecting my ideas about what scientific language looks like, to assess others in their efforts to argue for or against the mine from evidence. Clearly, I have some idea about what science language 'should' be, and I am starting to challenge those assumptions and question what scientific language is and how that relates to scientific literacy. We began to talk about what we as teachers can do to assist students in gaining scientific literacy while also challenging prior assumptions about what science language should or should not look like." (Felix, Macroteach Reflection, April 5, 2021)

Through opportunities to articulate his ideas of intelligence, interact with his peers' ideas of intelligence, and exposure to a specific example of how science students in two fourth grade classes were differently seen as intelligent in science based on the norms and expectations established by their teacher, Felix questioned his initial ideas of intelligence and how this had prevented him from identifying as a scientist.

Culture. We started working with framings/frameworks on this day by posing a question "Why does framing matter in school?" and then sharing a quote that was a description of part of a game of cricket. Most students in the U.S. are unfamiliar with cricket and the vocabulary and norms of the game were unfamiliar even though all the words were English. When asked what was going on in this description, most PSTs were unsure. One was familiar with cricket and smiling. We made the point of, if you are familiar with the game, the norms, and the vocabulary, this seems easy to understand. If you are not familiar with these, the description makes little to no sense. This is similar to framings and culture. If you are using the same framing and understand the culture of the person doing the describing, things seem obvious, but if you are not using the same framing/culture, things seem confusing even though to others, they seem obvious. This is not a difference in intelligence, it is a difference in framings/culture that is treated as

neutral and left implicit and as if everyone shares the same framing/culture that does not need to be made explicit so it can be better understood and worked with.

We then provided an example of what this same idea might look like in an assessment of skills. We created a visual that represented the example from Medin and Bang (2014):

> Suppose I know how to do one hundred things, that you know how to do one hundred things, and that our skills overlap 50 percent (we have fifty skills in common). Next assume that I am in a position of power and decide to make up a test of ability by randomly selecting twenty of my one hundred skills. When I give you the test you'll likely score around 50 percent, which is clearly inferior to my 100 percent. Of course if you were in a position of power and made up the test it would be a different story. But I can't test for your unique skills because they are likely irrelevant to my life and I lack them. As long as I'm in a position of power, I define what skills are relevant and I might even use my superior performance to justify my position of power. (p. 92)

We walked through this example to illustrate how even assessments that might seem neutral and objective are actually cultural, but it is difficult to see this when the person creating the assessment is doing so in alignment with their particular culture and experiences.

We then added a cartoon that illustrates a similar point. That of the human sitting behind a desk and stating to a line of different animals that "For a fair selection everybody has to take the same exam: please climb that tree" It is obvious that this exam is not fair across the monkey, elephant, and goldfish.

Culture Models. We next asked PSTs to work in their Macroteaching groups to create a model representing "What is going on with culture?" We asked PSTs to include: components of culture (What makes up culture?), grain size of culture (Where do you see culture? How does grain size affect it?), and interactions of culture (How do cultures interact? Think about positioning of cultures here too). I describe the model that Alice and her group made as I focus on how Alice was thinking about culture in this section.

Guardians of the Solar System Model of Culture. The model representing culture that Alice and her group created included a definition of culture as "a group of individuals that have common aspects of identity in common" (Class Slides, February 2, 2021, Slide 27). Alice and her group connected culture and identity seeing culture as shared identities. This group also included a list of components of culture, "ways of communicating, ways of thinking, practices, beliefs, values/interests, identities, skills/capabilities" (Class Slides, February 2, 2021). People who shared a culture, would tend to share these things. This group also noted that there were different types and sizes of cultural groups and provided an example of the culture of a group of friends, which could fit within the culture of a science subject studied, which could fit within a culture of Seniors in college, which could fit within a culture of the College of Education, which could fit within a culture of the university, which could fit within a culture of the state where the university was located. The group indicated that as the size of the cultural group got bigger, the group would become more diverse. This group included several ideas about people being part of and influenced by multiple cultures. They included an example of family culture, educational culture and social culture all forming a particular person and wrote that "the sum of our cultures forms the basis of our identity. Our collection of identities forms our self-image." (Class Slides, February 2, 2021, Slide 27). This group also included culture specific to schooling in their model with statements about the classroom, the school, the district, and students all having their own culture. Based on this model, this group recognized that everyone is part of multiple cultures, which interact in different ways for different people and that while people can share particular aspects of culture, there is also diversity within cultures.

"I don't want to" Scenario and Virtual Stickies Share Out. We (instructors) shared a scenario that we had used previously, but this time with the focus of identifying how cultures

played into the interactions between the student and the teacher in the scenario. This scenario was adapted from observations I made in a second-grade class as part of a study on student science practices during a teacher-university entomologist-created science unit. In this scenario, the teacher told the students, "Alright class, today in moth science we will be pinning moths just like real scientists. Each of you will get one moth to pin and observe." One girl, Raina, raised her hand and, when called on, said, "Ms. Carson, what if I don't want to pin moths?" The teacher told Raina that she could just watch her partner and Raina sat back from the table for the rest of the activity. We, as instructors, asked PSTs to read the scenario and think about the role cultures may have played in the interactions between the teacher, the class, and Raina, in particular. We anticipated that, coming after the previous day's activity reflecting on the different framings of science in the four scenarios we provided, (especially considering the framing scenario in which a Cherokee and Irish graduate student, Flo Gardipee, drew on her cultural perspective to seek and develop non-invasive methods for obtaining and studying buffalo DNA) and the group modeling of culture, that PSTs would identify or question what cultural perspectives on science might be motivating/influencing/at play in the scenario with Raina and Ms. Carson.

When asked to share via virtual stickies, how they thought cultures play into the interactions with Raina and Ms. Carson, PSTs shared responses/ideas that supported a thorough analysis of the scenario: 1) identified the specific cultural differences, 2) identified the need for the teacher to recognize the different and take steps to understand the student, 3) identified the problem with not recognizing and understanding cultural differences, and 4) proposed a solution to the problem created in the scenario. Some PSTs (4 of 17) identified that part of Ms. Carson's culture accepted that science justified the killing of organisms, while Raina's did not (i.e., identified the specific difference in culture/values). Four other PSTs noted that Ms. Carson never

asked Raina why she did not want to pin moths or tried to understand Raina's question/perspective (i.e., identified a problem in the interactions). Six of the seventeen PSTs addressed the consequences of the teacher not recognizing or valuing multiple cultural perspectives in science as Ms. Carson excluded Raina from science by stating that this activity is what "real scientists" do and then saying Raina could just not do the activity (i.e., identified why narrowly defining science is a problem in the classroom). Two of the seventeen PSTs shared that while Ms. Carson was trying not to force the student to do something she was uncomfortable with, she could have provided students with an alternative activity so they could still participate in science directly (i.e., identified a possible solution).

The above section only accounts for sixteen of the seventeen PSTs in the class. One PST questioned the premise of our guiding question by stating that they were not really sure culture played into the interactions and "Maybe Raina just doesn't like bugs." (Class Slides, February 2, 2021, Slide 42). This PST response, as well as other responses that did not directly address culture, but focused more generally on the need for teachers to understand their students and to consider how teachers are presenting what it means to be a scientist, have made me think that perhaps this scenario would be better used to think through possible science identities in the classroom and how teacher actions open up or constrain possible/valued science identities and/or that developing a shared class definition of culture could be useful before considering the role of culture in this scenario, as well as including a guiding question about what other information a person might like to have before deciding if cultural diversity is evident in an interaction. This is not because I think that strictly defining culture and analyzing it is the purpose of this activity, but more because having a shared definition might make it easier for all PSTs to engage in a conversation about how different cultures might present in science and the classroom, how to

recognize this, and how to better understand our own and other cultures, without the ease of opting out of the discussion by simply expressing doubt that culture is at play in a situation.

Alice. Alice worked to think through the ideas presented in class, even as it was difficult to align those ideas with her own framework of science. Alice expressed her frustration and the contradictions she was noticing in the examples of framings/frameworks in science and science class in her Weekly Reflection Journal entry on how she was thinking about framings/frameworks and their relationship with science and teaching:

> I think I have a better grasp on framing than I did last week or at the beginning of this week. I think the texts we looked at in class helped me understand framings that can exist aside from cultural framings. However, I am still a little bit confused on the importance/relevance of using framings that students don't personally relate to. For instance, what would be the relevance of teaching a topic from a cultural perspective that none of my students identify with? Should we even be doing this? I feel like the answer is yes but I don't understand why. (Alice, Weekly Reflection Journal, February 4, 2021)

Alice asked why it was important to teach a topic from a perspective with which her students were unfamiliar, which made sense as one of the first examples of the importance of framing that we (instructors) shared in class that week was a reading passage about a game of cricket, which was difficult for most of our PSTs to understand because they had no familiarity with the game of cricket. The message communicated with this example was that culture mattered and sharing an example or text that was based in a particular culture could seem straightforward to anyone who shared that cultural background, but would be incredibly confusing to someone with a different culture. Based on this example, Alice's question as to why she would teach a cultural perspective with which her students were not familiar makes sense. Why would a teacher intentionally share the cricket text with their American students with no familiarity with cricket? It would make more sense to share an example based in an activity with which students were

familiar. What we (instructors) did not make clear in this example was that the important thing was not to only draw from things that were culturally familiar to students, but to recognize the cultural factors underlying all examples and make those cultural assumptions explicit so everyone in the class could access and understand each example, or at the very least recognize when something was confusing because of an underlying assumption that students did not share.

Alice connected the idea of framings to science by writing, "Without alternate framings, some questions may never be asked about a scientific idea and some ways of approaching a problem may never be considered," (Alice, Weekly Reflection Journal, February 4, 2021). Perhaps reading the scenario with Raina and Ms. Carson wherein Ms. Carson only recognized one way of doing science supported Alice in writing that multiple framings were important for finding novel ways of approaching problems or questions in science. Other than framings/cultures informing the kinds of questions asked and the ways to approach solving problems, Alice also wrote that it was "important for students to be aware of framings when they read a text for homework, watch a video in class, listen to peers and scientists, or do their own research so that they may understand the motivations behind what they learn. I would love to be able to help students learn how to look at a text from a different perspective," (Alice, Weekly Reflection Journal, February 4, 2021). At this point, after the activities related to culture, Alice was most open to considering multiple perspectives in science, though she later focused strongly on the idea of science as made up of definitive truths. In this Weekly Reflection Journal entry, Alice tried out these new ideas about framings and culture. She later primarily rejected these ideas in favor of a view of science as made up of absolute truths, but she did consider the idea of there being underlying motivations behind things scientists said or content in texts.

Identities. Between Macroteach 2 and Macroteach 3, I facilitated an activity focused on identities. I drew from an excerpt of the Asters and Goldenrod chapter that PSTs had read previously. I asked PSTs to read the first four paragraphs of the chapter in small groups and consider which identities they noticed, how each identity mattered in the chapter, and who or what was involved in shaping each identity. I shared a broad definition of identity as "being a 'kind of person'" (Class Slides, March 11, 2021, Slide 35). We split up into four groups to discuss the identities noticed in the reading. Each group recorded their ideas on a slide in our shared Class Slides. Three of the four groups identified forester and botanist as identities and noted that the author identified as a botanist, but the advisor in the chapter had a different idea of what it meant to identify as a botanist. Two of the four groups also noted that the author self-identified as a woman. One group noted the author's skin and hair and eyes were different from a majority of students and posed questions about identities that a person does not choose, that are chosen by society, and how might those identities affect other identities a person might choose. After the small groups discussed and recorded their ideas,

I facilitated a whole group discussion about what identity was and how a person has an identity. In our notes, we recorded several main ideas about identities: that people recognize that you are a particular kind of person based on some criteria and that perhaps these criteria are determined by people deemed experts. A question of whether qualifications for identities mattered was posed, which identities required some sort of qualification or certification, which did not, and the notion of identities that are not skills-based, such as gender identities, was raised. Other ideas noted were that identities require interactions between two or more people or societies, so identities were socially constructed. Also, there was variation in how people thought

about what it meant to have a particular identity and that if people chose to use an identity to harm a person or prevent access to things, this was a problem.

This discussion of identities and the excerpt of the Asters and Goldenrod chapter raised the question of what counted as a science identity and who decided this? The author identified as a botanist, but the university official rejected her identification as a botanist and registered her for an introductory botany class so she could learn what Botany was. The university official did not recognize the author's botanist identity, but did think that through taking the correct courses and obtaining a Botany degree, the author could become a Botanist, which is what the author did. The author excelled in the university program and ultimately earned a PhD in Botany becoming one of the experts in this field. But even as she studied Botany in the university, the author shared the importance of the traditional knowledge that originally supported her interest in Botany and made her feel that she was a Botanist already. She mentioned a Navajo woman who did not have a university degree, but gave a talk as an expert on the flora of her valley. There were multiple ideas in this chapter that raised questions about what it meant to have a particular science identity and who decided this.

Willow. Willow documented her identity work in her Science Story editions and her Weekly Reflection Journal entries. Before this particular activity focused on identifying identities, Willow wrote in her Weekly Reflection Journal that:

> I'm noticing that my initial science story was already very tied to my identity. I get excited when I think about all my different identities and how they are interconnected. I have my family identity, my musician identity, my student identity…. I think that I could maybe state these identities more explicitly now…. I don't think that I really had a scientist identity growing up. I really wanted to, but it always felt like a science student identity, not like I was a 'real' scientist. I felt like this identity was something I had to work hard to prove I could earn," (March 4, 2021)

Willow had included multiple identities in her Science Story, from the very first edition, and she was excited about being able to name some of those identities whereas previously those identities were present, but implicit. Willow also noted that one of the identities she never really felt she had was that of scientist. Willow was a science student, but not a scientist.

Willow added to her third edition of her Science Story that an important part of her science identity development was building a relationship with one of her professors who was a female scientist. This professor recognized Willow as a scientist based on Willow's skill in the professor's class. Willow expressed the importance of this professor's recognition of her work:

> One of the main reasons I put so much effort into her classes was that I wanted to earn her respect as a scientist. I felt like if I could do that, I had made it as a scientist. I studied intensely for every exam and I went to office hours. I met with Dr. Frizzle after my last class with her ended, and she offered to write me a letter of recommendation and asked to keep in touch after graduation.…It was so powerful to feel significantly recognized by my role model. I think this was the moment I felt most accepted in the scientific community. (Willow, Science Story, April 20, 2021)

Willow shared how important it was to her that this particular professor respect her and her work. This professor's approval was important for Willow to feel like she belonged in the scientific community, which she had not felt before. Willow further explained what this recognition by Dr. Frizzle meant to her science identity:

> I suppose this also has a lot to do with my identity as a scientist. Being someone who doesn't personally know many professional scientists, I always felt like I wasn't a real part of the community. The science community was sacred, and I wasn't allowed to be a part of it. I had to prove that I could be. Dr. Frizzle validated that I was a real scientist because she was someone I saw as a real scientist, and she validated that I was skilled as a scientist too. (Willow, Science Story, April 20, 2021)

This recognition by a meaningful person, or expert in the field, supported Willow in recognizing and believing in her own identity as a scientist. This was also what supported Willow in

challenging the idea that a designated expert needed to recognize someone as a scientist for that person to identify as a scientist. While Willow needed this recognition herself, she did not want her students to feel they needed this sort of recognition if they themselves knew that they were doing science. Through considering what was required to have particular identities, Willow recognized her own identities, what was making the identity of scientist feel unattainable for her, when she first identified as a scientist and what supported her in doing so, and that she did not think her students should have to wait for a particular expert to designate them as scientists to identify as scientists.

Sociopolitical Issues in Science and Teaching

NOTE: All of these activities were in response to situations relevant to class. In the future, we would intentionally plan these into our Methods Class, probably before and after Microteaches and before and after Macroteaching.

When making the cultural nature of science explicit and working to expand what counts as succession the science classroom, it is inevitable that sociopolitical dimensions of science and teaching come up. In this section, I describe three activities that we (instructors) facilitated to support PSTs in recognizing and addressing sociopolitical issues in science and teaching, especially in their role as teacher. Each of these activities were designed in response to a particular sociopolitical issue that arose during Methods Class. The first activity I describe was designed in response to the Scholar Strike that occurred in the wake of the racial violence over the Summer of 2020, in particular police brutality and anti-Blackness. We (instructors) decided to do a teach-in on anti-racism, specifically related to science. The second activity was a class discussion that revisited our conversation norms in response to the heated whole class discussion that occurred as part of the What is Natural? Activity. Finally, I describe a two-day activity

focused on how to facilitate class engagement with sociopolitical issues in class that are particularly charged and have the potential to cause harm.

Anti-Racist Teach-In

The Anti-Racist Teach-In activity was taken up differently by different PSTs depending on their personal experiences and frameworks of science and teaching. Alice separated sociopolitical issues from science, which meant she thought about ways to address sociopolitical issues in her classroom generally, but not as interconnected with science itself. Willow saw science as already connected to and influences by social issues, so she took up the ideas in the Anti-Racist Teach-In in a way that integrated her thinking about science, teaching, and the sociopolitical dimension of science. Felix connected ideas of racism in science and teaching to his goal of creating a high-quality science curriculum that would provide equal access to science to all students while also valuing diverse student ideas and ways of thinking.

The Activity. In the second week of the Fall Semester, we (instructors) had planned to spend the first day of that week doing a model unit based in the AST Framework and which would surface multiple ways of thinking about our chosen phenomenon as this phenomenon was very obviously tied to social issues. We still did this, but only after we spent the first part of class focused on what we called an "Anti-Racist Teach-In" in alignment with the Scholar Strike. The Scholar Strike was enacted across campuses in the US in response to the broadly publicized evidence of police brutality and anti-Blackness in the Summer of 2020, in particular the murders by police of George Floyd and Breonna Taylor, the lynching of Ahmaud Arbery, and the shooting of Jacob Blake. As instructors, we were concerned about how a conversation about racism in science and teaching might go in the second week of class, especially an entirely virtual class on Zoom, without well-established relationships and norms in the class. At the same

time, the reason for the Scholar Strike was representative of the sociopolitical reality that all of us were living and teaching in.

We (instructors) discussed how we could address this issue in an explicit way that would be clearly relevant to our class and would provide opportunities for useful dialogue. We decided to focus on a discussion of the connections between racism and science, as well as racism and teaching. We began by sharing some questions to consider for interactions in class, especially when having what we called "contentious conversations". We noted that people are different and have different ideas and experiences. We posed the following questions for PSTs to consider: "What do you do when someone says something that upsets you? What do you do when someone brings to your attention that you've upset or hurt them? What would you want your students to do in these situations? What would you want someone else to do it they hurt you or you hurt them?" With these questions, it was our intention (as instructors) to remind PSTs that they have ideas about how to interact with others, even and especially when someone else shared an idea that upset them. This approach was also taken as a way to continue our co-construction of class norms rather than instructors deciding on norms for the entire class. This method could be problematic when dealing with things like conversations about injustices, such as racial injustice.

Later on in Methods Class, we addressed norms for these types of conversations differently, as I describe in the following sections. Part of the reason this conversation did not end up being harmful was that our PSTs were predominantly white, which meant that any harmful questions or statements related to race were less likely to personally harm a peer. This is not a reason to follow the approach I have described here, but a reason we did not have immediate negative feedback about this approach. Another reason this conversation probably

was not as harmful as it could have been was that several PSTs had practice discussing ideas of racial injustice through other classes they had taken.

After posing questions to think about how to interact with one another if ideas different from our own were shared, we asked PSTs to share their ideas about how racism was connected to science and teaching so we could all have a sense of how our class community was thinking about this. We used a padlet with the prompts, “How are science and issues of racial justice connected? Include examples or evidence or questions, if possible.” and “Why does the current social climate matter for us as teachers? Include examples or evidence or questions, if possible.” PSTs shared a variety of ideas as to how science and issues of racial injustice were connected.

One idea was that science being used to justify racism was something that happened in the past, “‘Science’ (and religion) used to be used to justify slavery” and “thanks to modern, true science, notions saying one race is less than another due to lack of natural selection or brain size have been shown as false” (Science and Racial Injustice Padlet, September 8, 2020). Another idea was that the achievements of people of Color had been erased or co-opted, “the scientific achievements of people of color are often not highlighted or credit for their achievements is given to their white colleagues” (Science and Racial Injustice Padlet, September 8, 2020). Others brought up the lack of representation of scientists of Color in schools, “I think that science, as is typically taught in US public school, is predominantly from a very Eurocentric perspective. Most of the scientists we learn about are white males. It's harder for students of color to see themselves represented in science.” (Science and Racial Injustice Padlet, September 8, 2020). PSTs also wrote that there was a lack of access to the benefits of science in communities of Color, citing the racial disparities in hospitalizations and deaths due to COVID-19, “This pandemic is a good connection between racial injustice. A majority of large break outs are in communities of color

due to the fact they don't have as much access to healthcare…" (Science and Racial Injustice Padlet, September 8, 2020). Finally, PSTs brought up the systemic nature of racism in science, "Science is widely seen as a way for advancement, both technologically and economically. There are some systems that can keep certain peoples outside of the scientific community, therefore restricting possible advancements in technology and social status." (Science and Racial Injustice Padlet, September 8, 2020).

The ideas elicited indicated that PSTs were aware of general connections between racism and science. Many of the responses focused on science as the domain of white males and that this created problems, in particular, for people of Color in terms of lack of representation and access to science education, careers, and benefits. The only semi-specific connection between science and racism was the mention of science being used to justify slavery and notions of genetic inferiority/superiority of different races and these were placed squarely in the past. The current issues of racism in science were seen as issues of access and representation, but not that science itself was or could be influenced by racism. This idea of current science being influenced by racism was raised in the whole class discussion that occurred after sharing ideas in the padlet.

We facilitated a class discussion about the ways racism was connected to science and teaching based on PST ideas. In this discussion, a PST shared that "As science teachers…we have an opportunity to approach some of those more politically charged topics from an un-politicized science perspective. Can combat misinformation and preconceptions through that lens and it carries more weight than us just giving our opinion. It addresses it through a different, neutral lens." (Class Discussion Notes, September 8, 2020). This idea of using science to address politically charged topics is interesting and something we (instructors) would encourage, as

science is not separate from the sociopolitical. However, we would push on the idea of science as "neutral". Another PST also immediately pushed back on this idea of science as neutral, saying:

> Science isn't 100% unbiased all the time. It's not objective truth. It's a collection of human notations over time. A lot of our conceptions and history and the way we go about science is racist. Bring in discussions about how science can be problematic and the assumptions we bring into our data influences what the data says. Important to bring into your classroom discussions of ethics and bias before bringing in the idea that science is an objective truth because it's not. (Class Discussion Notes, September 8, 2020)

Other PSTs built off this idea that science was not objective truth or neutral by raising the point that it mattered who did the science and where scientific information came from, "because often the white male perspective is continuously perpetuated" (Class Discussion Notes, September 8, 2020). While there were some ideas of science and sociopolitical issues as being connected, the overwhelming theme of PST ideas shared seemed to be that sociopolitical issues mattered even though they were not directly related to science. As one PST shared, "When things are happening in the world that are confusing and you need to process it, it's hard to do work. As teachers it's important for us to help our students work through whatever they need to work through, even if it's not technically science." (Class Discussion Notes, September 8, 2020). It is important to recognize the world beyond the science classroom and that this world matters in the science classroom. And, it is interesting that even when the discussion prompt was specifically how issues of racism were connected to science, many PSTs responded from a place of, issues like racism matter, even though they are outside of science.

At the end of this discussion, the graduate student who shadowed Methods Class for the Fall Semester, shared an experience she had when teaching biology in South Korea. She shared:

> I was about to teach DNA and I wrote deoxyribonucleic acid and asked them [students] if they could pronounce it. One student pronounced it and everyone said, wow! Just by saying they English full name, he was

> considered smart. Once student: is there a Korean word for DNA? They did a quick investigation of their science textbooks and saw all scientists were white males and they asked if all the units and words were from English, so science is English knowledge? (Class Discussion Notes, September 8, 2020)

The graduate student, June, shared this example of how the science presented and the way it was presented sent the message to her students that science was the domain of white men who spoke English. Her example brought the discussion back to ideas of racism as present in science and science education and also reiterated the importance of representation in science. What was easy to miss in this story was the implicit question of where the Korean science was. Throughout the discussion in class, PSTs identified the lack of representation beyond white men in science, but no one questioned where or what the science knowledge was that was generated by everyone else.

After the whole class discussion of PST ideas about racism and science and connections to teaching, we (instructors) shared an example of racism in science that had occurred recently at our university. We shared the position of power that an individual at our university had occupied, the racist views he had shared in a blog post and also stated were grounded in science, specifically genetics. We also shared the research article which this individual used to justify his argument of an intellectual hierarchy based on race and outlined his argument alongside the problems with each step of his argument. We ended this activity with a set of questions to ask yourself as a science teacher before introducing ideas to students: “Who is doing the study? Who is the author writing for? What was the author’s purpose in doing this particular study? What are the author’s starting assumptions? What are the available critiques of the study/way of interpreting and presenting data?” (Class Slides, September 8, 2020, Slide 6). We included an

idea that as science teachers, we should ask all these questions and also support students in asking all of these questions themselves.

Alice. After the Anti-Racist Teach-In activities, Alice reflected on what she could do as a teacher in relation to social justice issues. She identified the importance of creating "an inclusive and welcoming classroom" (Alice, Weekly Reflection Journal, September 10, 2020) and that she would do this by "providing my students with a space to be themselves and have honest dialogue with myself and their peers" (Alice, Weekly Reflection Journal, September 10, 2020). Alice added that part of supporting this kind of honest dialogue involved her "provid[ing] them with the tools to think critically and form understandings based on fact. However, as important as it is to form opinions on issues, I want my students to understand that it is always acceptable to expand upon a belief or change a perspective as they learn more about issues," (Alice, Weekly Reflection Journal, September 10, 2020). Alice reflected on the importance of dialogue, critically thinking, and expanding on or changing ideas based on new information or evidence. Alice wanted her students to be able to do this when considering sociopolitical issues. This was also evidence of how Alice, like many of her fellow PSTs separated sociopolitical issues from science. Sociopolitical issues should be discussed and opinions formed. This was different from science, which was made up of truths that teachers had an obligation to communicate to students.

In terms of connecting science to sociopolitical issues like racial justice, Alice noted that while it "feels small in comparison to the weight of some societal issues I will have to address with my students", like many of her fellow PSTs, Alice felt that representing scientists of different genders, backgrounds, cultures, and identities in her classroom would hopefully help students to "feel empowered and encouraged by seeing famous scientists that they can personally identify with." (Alice, Weekly Reflection Journal, September 10, 2020). Alice expressed a deep

sense of caring for her students and a desire to make her classroom a place where she and students could have honest dialogue about a broad range of topics. She saw a place for sociopolitical issues in the classroom, but perhaps not a direct connection between science and sociopolitical issues, which made sense considering the lack of an explicit connection between science and sociopolitical issues in the Anti-Racist Teach-In activities.

Willow. Willow also took up the idea of broader representation as part of enacting social change in her science classroom, writing, "In my classroom, I want to focus on representing women, people of color, and members of the LGBTQ+ community in science. I want to make sure to use examples from these individuals and highlight important discoveries that were not made by straight white males." (Willow, Weekly Reflection Journal, September 10, 2020). This was a common idea that was shared in the Science and Racial Injustice padlet and in the subsequent whole class discussion.

This idea of representation in science was important and personal for Willow, as she expressed in her Science Story in relation to her science identity and her feelings of not belonging in the science community because of her gender identity. Willow took this idea of representation as it was shared in the whole class activity and went further with it, stating that she wanted "to highlight why it can be difficult to find these [diverse] examples, including disparities in access to education," (Willow, Weekly Reflection Journal, September 10, 2020). Willow shared that it was important to both include representation of diverse scientists and explicitly discuss why these scientists were often not included in science classes and textbooks.

Beyond representation, Willow stated a need to address the root issue behind the common lack of diverse representation in science. Willow then shared an idea to work toward rectifying this representation issue in science itself. Willow wrote, "I want to include examples of scientific

theories from other cultures. I think that talking about science history can be an interesting way to bring up social justice issues that still impact science (and the rest of society) today." (Willow, Weekly Reflection Journal, September 10, 2020). Willow stated her idea to go beyond representation of diverse scientists to bring in actual diverse scientific theories and discuss the history of science as a way to address the ways the social and science were interwoven. Willow noted that social justice issues impacted science directly and that this was still relevant in the present. Willow recognized that the science of straight white males left out a lot and she saw actively bringing those scientific theories from other cultures into her classroom as a way to work for social change.

Felix. Felix incorporated his personal goals to "help fight against systemic racism in our schooling system" through "developing ethical and effective curriculum" (Felix, Weekly Reflection Journal, September 10, 2020) into his reflection on what he as s teacher could do to support his students in thinking about social justice issues while also teaching science. Felix reflected on his idea that a major problem was that education was not equal across schools and that "by developing the best curriculum for students to learn from, I hope to shrink the differences in education quality," (Felix, Weekly Reflection Journal, September 10, 2020). Felix thought about systemic racism in the education system as, at least partly, due to different access to high quality curriculum.

In addition to providing the same high-quality curriculum to all students, Felix shared his idea of the importance of the individual student and the ways they formed knowledge. As Felix explained, part of this best curriculum, was a focus on student ideas and he saw this focus on student ideas as a way to increase diversity of ideas in the classroom. "This also avoids present[ing] knowledge in a Eurocentric, white male perspective, and changes it to the

perspectives of each student individually as they are forming their own knowledge," Felix, Weekly Reflection Journal, September 10, 2020). Felix reflected on two concepts that were important to him: providing equal access to high quality science curriculum and supporting individuals in generating their own knowledge. Part of this individual knowledge generation would also involve sharing perspectives with the class so students would be exposed to multiple ways of thinking about each topic. Felix assumed that the students in the class would provide a diverse array of ways of thinking. Finally, Felix added that, "as a member of the LGTBQ community, I also strive for recognition of social injustices that occur outside my discipline, as well as the injustices science has perpetuated throughout human history," (Felix, Weekly Reflection Journal, September 10, 2020). Felix noted that social injustices were relevant to his role as a teacher whether these injustices were directly related to science or not. He also placed injustices in science in history, possibly implying that these injustices related to science occurred in the past.

Felix took up the ideas discussed in the Anti-Racist Teach-In in ways that mattered to him and connected to how he was already thinking about science and teaching. The curriculum he wanted to develop to make sure other students were presented with the accurate representation of science that he was denied in high school, was the way he saw he could tackle systemic racism in schools. Valuing individual student knowledge formation was a way to avoid taking a solely Eurocentric, white male perspective. Felix also recognized that broadly speaking, there were multiple social injustices that occurred that he was more or less familiar with and that these mattered in his science classroom whether or not they were directly related to science.

Addressing Racial Injustice and Patriarchy in the Classroom

All three focal PSTs reflected on their discussion of the two scenarios and stated that sociopolitical issues should be discussed in their classroom. Alice focused specifically on how to address the topics raised by the scenarios. Willow and Felix identified the root issue that made the topics feel uncomfortable to discuss, that they were "taboo" and went against "societal rules". Willow and Felix also stated that through establishing discussion norms, they could support students in discussing these uncomfortable topics. Felix went a step further and explicitly stated that doing this would be a way of "fighting the societal rules and conceptions that are established in normal discourse" (Felix, Weekly Reflection Journal, November 12, 2020).

Justice-focused Scenarios. After a brief discussion to re-establish discussion norms, we (instructors) re-introduced two scenarios that we had presented in a set of scenarios the previous week. Each of these scenarios described the interactions between one or more students and an educator with differing frameworks of science and what happened when those frameworks were recognized and included or not by the educator. We purposefully selected two scenarios that surfaced particular social issues that people in the US find it difficult to talk about. We chose a scenario centered around a joke about menstruation in a middle school classroom and another scenario about a Black student's comment about anti-Blackness in the criminal justice system within a Forensic Science lesson. In both scenarios, a student brought up a topic that the educator found uncomfortable.

Menstruation Scenario Discussion. In the scenario with Mr. Franky and Blue, Mr. Franky was facilitating an activity on genetics, specifically a pedigree chart showing the gene for hemophilia among generations of English nobility. The teacher asked the class to look at the chart and "Based on what we know about genes, I want to know who you think has the disease,

or who do you think will bleed more?" Blue, a girl sitting in the front of the class raised her hand and when called on said, "I'm glad I'm not the only one who has to worry about bleeding right now." There was a silent pause in the class. Blue nervously laughed. Mr. Franky did not know what to do, let out a chuckle and tried to move on. Blue left class and when she returned after class, it looked like she had been crying.

We (instructors) asked the class why this situation was difficult to discuss and who found it difficult. In the whole class discussion, one PST shared that he "went to an all-dudes school it was not discussed much there" (Chat, November 9, 2020). In contrast, one female PST shared that her "health teacher in 7th grade directly called me out and asked m[e] if I had started my period:)))))" (Chat, November 9, 2020). There were several horrified responses and then the PST who initially shared responded to a previous question from Timothy as to whether menstruation was discussed at all at his all-male school, "We had health class that was a bit of a blow off, but we did learn about it academically, but it was still just something guys don't have to deal with it felt like" (Chat, November 9, 2020). The general consensus seemed to be that the topic of menstruation was not something that males discussed and it was upsetting when females were asked about their personal experiences with it. As a class, we asked why this topic was not talked about, why it was uncomfortable to talk about it and why this was seen as a topic that was not for boys/men to discuss. As a class, there was difficulty even talking about talking about this topic.

Racial Justice Scenario Discussion. In contrast to the scenario where the educator had trouble talking about menstruation, PSTs had a lot to say about discussions of racial justice in the classroom. We read a scenario about Mr. A and Amir that was drawn from an article by Calabrese Barton and Tan (2020). This scenario was set in a forensic science investigation in the sixth grade:

> During the last session, students pulled their ideas together in a crime scene investigation. Mr. A explained that they were responsible for gathering and analyzing data so they could accurately find and convict the right criminal. He emphasized the importance of being fair and using data as evidence. Amir quickly interrupted by calling out 'Unless you're Black! If you're Black, you'll be convicted.' Mr. A seemed caught off-guard by Amir's comment, responding, 'I like the passion in that statement, but let's make sure we talk about that somewhere else, other than this classroom, at the moment. If you want to talk about that later, we absolutely can.' (Calabrese Barton & Tan, 2020, p. 435)

After reading through this scenario, PSTs immediately stated that teachers needed "to address racial equity somewhere" and "if a student brings this up, there is a need to talk about it. Don't brush it off. Make space in your lesson for that." There were several statements about being uncertain how to deal with this, but needing to prepare and return to the conversation before one PST stated firmly, "If you're planning to bring up a conversation on the criminal justice system, this is something you should be prepared for" (Class Discussion Notes, November 9, 2020). PSTs brought up multiple reasons why conversations about race did not happen, especially in white spaces. One PST stated, "Conversations of race don't happen and because they don't happen, people aren't comfortable talking about them. We all have internalized racism and it's really hard to work on because we don't admit it. It's easy to avoid the conversation all together." (Class Discussion Notes, November 9, 2020). Both menstruation and race/racism were topics that people were uncomfortable talking about, but PSTs stated that teachers needed to be prepared to talk about race and racism. As one PST pointed out in the chat, "Did this take place in 2020, because I think it would be a different response" (Chat, November 9, 2020), PSTs may have had more practice talking about racial issues in the wake of the racial violence and the resulting protests and surge in the Black Lives Matter movement than they had before the summer of 2020. In contrast, PSTs had had little experience talking about menstruation.

In both cases, when we discussed sociopolitical issues in science education, while PSTs agreed that issues of race should be discussed in schools, they did not necessarily make a clear connection between the sociopolitical issue and science itself. The three focal PSTs reflected on these scenarios in their Weekly Reflection Journal that week and each PST thought differently about these scenarios and what they thought a teacher should do.

Alice. When asked how she was thinking about the ways the teachers handled the situations in the two scenarios, Alice focused on the specific scenarios. Alice thought carefully about the particular situations described in each scenario and while she acknowledged that it was always easier to evaluate a situation after it had happened, she thought that the teacher should have acknowledged the menstruation joke more and at the very least, not responded with shock.

In the racial justice scenario, Alice thought the teacher was "way too dismissive of the student's comment. It should have been acknowledged." (Alice, Weekly Reflection Journal, November 12, 2020). Alice later stated definitively, "I don't think the comment made about menstruation should have necessarily been expected, and it would have definitely caught me off guard. The comment about racial injustice, however, should have been expected and shouldn't have been ignored," (Alice, Weekly Reflection Journal, November 12, 2020). Alice thought carefully about each scenario and considered what she thought would have been the best course of action for the teacher. She thought that teachers should be as prepared as possible, but that they could not prepare for everything so, "I think our best bet is to acknowledge the comments our students make, assess if it should be addressed further (Mr. A's situation should, but I don't think Mr. Franky's should), then move on with the lesson, and bring up the topic at another time if necessary." (Alice, Weekly Reflection Journal, November 12, 2020). Alice drew from her framework of teaching, in which student ideas and experiences mattered and should be

welcomed and acknowledged in the classroom to think through the teachers' actions in these scenarios.

Willow. Willow reflected on the class discussion of the two scenarios and focused on why these situations were uncomfortable in the first place and what could be done about that. Her first statement was, "I think these situations were a bit uncomfortable in these classrooms because they are taboo subjects in our society." (Willow, Weekly Reflection Journal, November 12, 2020). Once she had identified why these situations were uncomfortable, Willow reflected on what teachers could do to support conversations about difficult subjects, "Thinking back to my own experiences in classrooms where we talked about subjects that we commonly think of as being difficult to discuss in everyday life, I think some things that made me feel more comfortable were establishing classroom discussion norms." (Willow, Weekly Reflection Journal, November 12, 2020). Willow considered the role norms could play in supporting students in having conversations about uncomfortable topics. She also wrote that teachers should, "be aware of topics that are prevalent in the media, and be prepared to have discussions about them in their classrooms…. students won't be able to focus on science when issues such as racial injustice are brushed to the side," (Willow, Weekly Reflection Journal, November 12, 2020). Willow thought that teachers should be aware of these sociopolitical issues, but also saw them as separate from the science taught in the classroom. Willow identified the root cause of each teacher's avoidance of discussing the topic in each scenario, that the topics were taboo and the teachers were uncomfortable. She wrote that teachers should be prepared to discuss topics like this and that well established class norms could support these kinds of conversations. She did not connect these conversations of sociopolitical topics directly with science teaching.

Felix. Similarly to Willow and Alice, Felix noted that it would be difficult to predict every possible instance of a difficult conversation in class. Like Willow, Felix thought that establishing norms for discussion would be helpful in these situations, "A more practical approach would be to have pre-established views and purposes when it comes to student discourse would help guide oneself during an 'awkward' conversation." (Felix, Weekly Reflection Journal, November 12, 2020). Felix focused on how to establish broader structures in class to support awkward conversations.

Felix continued on to state a broader goal in his classroom that he saw as useful, "as an overall goal, fighting the societal rules and conceptions that are established in normal discourse could help turn those situations into learning opportunities," (Felix, Weekly Reflection Journal, November 12, 2020). Felix offered a goal behind the discourse norms he thought would be useful, a goal of challenging established rules of what counted as "normal". Felix elaborated on his idea of what it meant to challenge social rules of what was normal, writing, "Of course, what is 'bad' or 'good' societal standard comes down to my own opinion, then that brings in morals, and I have not thought about those yet." (Felix, Weekly Reflection Journal, November 12, 2020). Felix moved beyond the specifics of the two scenarios to address what he saw as the root issue in both scenarios, that society said these topics were not normal and therefore difficult to talk about, and, like Willow, offered a way to support students in having these conversations anyway. Felix named this teacher action as "fighting the societal rules and conceptions" and stated that his goal was to make these awkward moments into learning experiences. Like Willow, Felix was considering these awkward moments to be opportunities to explicitly discuss why these topics felt uncomfortable to talk about and to challenge the status quo by discussing them anyway.

"Courageous Conversations"

All three PSTs recognized that sociopolitical issues would arise and affect their students. All three focal PSTs were also concerned about being prepared to facilitate conversations about these issues in ways that supported their students. Alice focused on sociopolitical issues as solely coming from outside her class and not directly related to science class which aligned with her framework of science as made up of truths and separate from the sociopolitical. Willow and Felix, in contrast, saw science as connected to sociopolitical issues and focused on ways they could actively prepare to support students in having these kinds of sociopolitical conversations in their classes in ways that did not perpetuate harm. Willow considered not having these conversations to be a form of harm as this would be passive support of a harmful status quo. Felix saw these conversations as being integral to his science classes and part of classroom discussions, possibly because of his recent experience with a science-focused classroom discussion raising sociopolitical issues in a harmful way he had not anticipated.

Part 1: Norms and Goals. Throughout Methods Class, we (instructors) had expected PSTs to consider, plan for, and incorporate social, political, historical, and cultural aspects of the science they were teaching into their lessons/units. We did this through including explanations of the social and historical dimensions of phenomena as a required part of lesson/unit planning. We also required PSTs to identify at least two different framings/frameworks of the science concept and phenomenon they were teaching in their Macroteach and to incorporate these into their unit. Identifying, investigating, and incorporating the social and historical contexts of science and phenomena was an expected part of teaching in our class. While we had discussed conversation norms and the importance of facilitating sociopolitical and cultural discussions in the classroom, we realized during the third Macroteach, that we (instructors) needed to provide more in-depth,

explicit explanation and modeling of how to facilitate these discussions in ways that were less likely to perpetuate harm.

During the third Macroteach, the class investigated the possible creation of a pit mine in Minnesota on what were the ancestral lands of the Menominee People. As part of this unit, the Macroteachers asked their students (their peers who were acting as students) to share ideas about the Menominee People. During this sharing, some harmful stereotypes about Indigenous people were surfaced. We (instructors) pulled the Macroteachers into a breakout room to make the Macroteachers aware of the harmful comments and discuss what to do next. What we realized was that PSTs did not know what to do next or how to avoid this unintentional surfacing of harmful stereotypes in a public space. As a result, Timothy and I created a two-part lesson on what we called "Courageous Conversations". We thought of these conversations as courageous because it took courage to participate in conversations where potentially harmful ideas could be shared and to actively work to mitigate our own harmful ideas. In the future, we would call these "critical conversations" which would indicate their importance and not imply that the teacher must be especially courageous to facilitate a conversation about people's lived experiences.

Part 1 of the lesson was spent defining "Courageous Conversations" and discussing what they were, why we might engage in them, and how to do as little harm as possible. Part 2 of the lesson was a model of facilitating a courageous conversation about the recent rise in anti-Asian hate in the US.

We started by establishing conversation norms as a class. We first laid out our expectations as instructors and the intentions behind each expectation. We then discussed as a class what norms would best support us in meeting these expectations and having a useful conversation. We (instructors) set the following expectations: 1) Neutrality is not an option, 2)

These conversations will get emotional and personal. It's ok to turn off your mic or camera as needed, 3) Focus on listening to understand, 4) Strive for intellectual humility*, 5) Recognize difference between opinion and informed knowledge, 6) Let go of personal anecdotal evidence and look for broader social patterns, 7) Notice your defensive reactions and use as entry point to gain deeper self-knowledge, 8) Recognize our social positionality informs perspectives and reactions." (Class Slides, March 30, 2021, Slide 22). We noted that expectations 4-8 were taken from Sensoy and DiAngelo's (2017) book. PSTs then came up with the following norms for discussion: 1) Let people finish speaking, 2) Don't jump to conclusions, Before reacting, think of and ask clarifying questions, 3) Pay attention to how much you and others are talking. Leave space for others, 4) Have a place to write your thoughts so you don't feel like you have to jump in and interrupt (personal, floating virtual stickies)." (Class Slides, March 30, 2021, Slide 22).

As we were discussing conversation norms, a PST shared a TED Talk on how to have constructive conversations, so we shared the link in our slides. The next step in Part 1 of this lesson was a definition of what a courageous conversation was. Timothy and I had come up with some bullet points of how we were thinking about the types of conversations that required careful planning and norming. We shared that there was "the potential for people to be hurt because of the personal nature of the conversations" as the conversations touched on deeply held beliefs and personal understandings of the world. We also shared that there were "multiple perspectives, drawn from both lived experiences and life knowledge" that could be applied to these conversations. Connected to this was the idea that "people have emotional attachment to their perspective and subsequently might have only thought about the issue from their own perspective, not that of others". We also included that "there are social, political, and historical influences on these issues that shape how people think about, talk about, and act on them", and

finally, that these were “conversations/topics that usually get silenced” (Class Slides, March 30, 2021, Slide 24).

We posed a discussion question, “What do you all think about these conversations? Has anyone had them? If so, what was the setting?” Some of the things that came up in the discussion were a sharing of a TED Talk by Brené Brown on the power of vulnerability and questions about how to make these conversations safe for people. This question came from a concern that some people’s ideas about the conversation topic could be harmful to others in the room or the topic itself could be traumatic for some people to discuss. This led to more questions such as, “Who is in the room? What is the purpose of the conversation? Who is this for? Does everyone need to be part of the same conversation?” (Class Slides, March 30, 2021, Slide 25). As PSTs considered these questions, we moved on to the next section of this lesson, which focused on when courageous conversations happen.

We (instructors) shared that we thought there were two separate times when we might see these types of conversations, “1. Response to violent or unjust events in the class, the school, the nation, or the world at large, 2. Planned acts of resistance to otherwise unchallenged norms of oppression” (Class Slides, March 30, 2021, Slide 26). In making this statement, we (instructors) were trying to be explicit about conversations like this occurring because something outside the class required the teacher to make space inside the classroom for students to process it. This was the kind of conversation that most PSTs seemed to have been considering.

We also wanted to be explicit that there was another type of courageous conversation to have and that was the kind the teacher planned for as a way to challenge an unjust status quo. For example, if Mr. A had planned to facilitate a discussion of the ways systemic racism are woven through the US criminal justice system and the ways this system could be reformed so the

forensic science used was not based in a biased system, this could have been a courageous conversation. Mr. A would prepare for this conversation and it would be the main focus on the lesson. We (instructors) also pointed out some things to consider about courageous conversations, such as the importance of relationships with students as a classroom community where everyone holds each other to norms of respect and care were essential for supporting these conversations. We also pointed out that, as we had seen in all three Macroteaches so far, "it is very much possible to focus a class on both science content and social, historical, or political issues tied to the science. Intentional structuring of lessons and unit plans helps you prepare to have these conversations" (Class Slides, March 30, 2021, Slide 26).

We (instructors) shared that we had personal experiences with having conversations like these after events like DACA and border control issues, the Parkland shooting, Trump's election, and the Coronavirus outbreak. Finally, we shared that it was "ok to stop the violence but hold off on having the conversation until you are ready," with the advice to learn about the event so you can facilitate a meaningful conversation. Next, we (instructors) shared why we thought these conversations should happen. Our first point was that students are human beings and if the teacher is distracted by an event, students are probably feeling the same way. We also pointed out that not addressing the event in class would not make it go away. Also, we were explicit that, "Science is shaped by people, so science is social, science is political, and science is historical." (Class Slides, March 30, 2021, Slide 30). We shared some examples of science as social, political, and historical.

Finally, we posed a discussion question, "What are the possible outcomes of having these conversations? What are the possible outcomes of not having these conversations? Who do these outcomes affect directly and indirectly?" (Class Slides, March 30, 2021, Slide 30). We next

addressed the question of who your audience was in these conversations. In this slide, we specifically brought up the importance of knowing your students and then knowing if all students were of the dominant perspective or if students who are directly hurt or affected by the concepts you will be discussing. Depending on who is in the room, there might be more leeway for working through hurtful ideas as a class or there might be a need for stricter norming and possibly a creation of separate groups for separate conversations depending on the purpose of the conversation. We proposed a question to consider, "What structures can you set up to avoid this situation where you have to choose between protecting one student and potentially shutting down the growth of another student (who probably needs the growth)?" (Class Slides, March 30, 2021, Slide 32). This led to the next slide on the goal of the conversation. We (instructors) shared six possible goals of the conversation and left the seventh space filled with question marks as there could be multiple different goals for these conversations depending on the topic, the students, and what seemed necessary in the context. We wrote on the slide and stated that, "it is important to know what your goal is and to state that every time to the participants of the conversation" (Class Slides, March 30, 2021, Slide 34). A PST shared a YouTube video link to a video on social media echo chambers in response.

Part 2: Class "Courageous" Conversation. In our next class session, we (instructors) modeled one way to facilitate a courageous conversation focused on a harmful current event, the rise of anti-Asian hate in the US. We began by revisiting the expectations we had for the conversation and the goals we as a class had agreed upon in the previous session. We (instructors) then shared the goals we had for this particular conversation and the ways that we anticipated working toward those goals in this class conversation. These four broad goals were to: "have a space to reflect on this current issue/injustice", "help students listen to and understand

feelings and ideas different from their own", "start taking steps toward taking action to disrupt injustices as they are identified", and "recognize social, historical, political factors at play and how they influence these feelings and ideas" (Class Slides, April 1, 2021, Slide 41). We included a note about our teaching decisions before beginning, sharing with PSTs that we were providing a space for personal reflection first so the teacher could see student ideas before they were shared with the rest of the class in order to prevent harmful ideas from being unexpectedly shared. We also were providing resources on the issue for students to look into so that when it came time to discuss in small and large groups, students had evidence to draw from beyond possible initial assumptions. We also noted that it was important to be aware of the procedures and support systems in place at your institutions before facilitating these conversations, for example, by talking with school counselors first to make sure they are available and aware that students may reach out to them for support. We (instructors) then provided a trigger warning that this conversation would "be centered around the recent spike in violence perpetrated against people of Asian descent" and that the next slides would include examples of "historical, political and contemporary social and physical violence that people of Asian descent are experiencing" (Class Slides, April 1, 2021, Slide 43).

This conversation took place during the COVID-19 pandemic and at that time, there was an increase in anti-Asian sentiment and violence across the US in response to misinformation and speculation surrounding the origin of SARS-CoV-2. We included links to the university's counseling and psychiatric services. Timothy began the conversation by sharing why this particular issue was personal to him. Timothy shared the fear that his partner, a Chinese woman, and her family had been living with due to the rise in violence perpetrated against people of Asian descent to the point where she was too afraid to go to places like the grocery store alone

because of the attacks that had been occurring across the US. Timothy then shared that we (instructors) had compiled some resources for PSTs to look over to learn more about the current issue and the historical, political, and social factors that contributed to the current situation.

We provided multiple break out rooms in Zoom that PSTs could freely move between depending on how they preferred to work. One breakout room was for individual, quiet exploration of the materials, another was for individual exploring, but with room to talk with other, another was for PSTs who wanted to talk through the materials as they went through them, the main room was where instructors would stay and be available to discuss or listen to ideas. We had organized the materials by topic and included a slide of virtual stickies for PSTs to add notes/thoughts as they felt appropriate. The first slide was a set of materials focused on historical instances of anti-Asian sentiment (1800s-1950s). The next slide of materials was of historical instances of anti-Asian sentiment (1950s-2000s). We included another slide with information on microaggressions and an example of microaggressions specifically targeting Asian males. We included another slide with information and a reflection question focused on the model minority myth. The next slide of materials focused on recent violence and macroaggressions. Finally, we included a set of information about the ways this violence was connected to the COVID-19 pandemic.

After providing PSTs with time to explore the materials, we asked them to work with at least one other person from their Macroteach group to think about where a courageous conversation could have been planned into their Macroteach, what it would look like, what the goal and outcomes would be. PSTs included a detailed plan for incorporating a courageous conversation into their Macroteach. While we had provided an example of how to facilitate a conversation around harmful issue not directly connected to science content, we (instructors)

wanted to support PSTs in thinking about these kinds of conversations as part of their planned science teaching.

Applications to Science Teaching. Alice's group discussed, but did not end up creating a slide.

Willow and her group decided that this kind of conversation could have been planned for when their group discussed the importance of names. Their Macroteach was centered around the ecology of a plant native to Japan, but that was often found in the US. In Japan, the plant was called things like "fleece flower" and had multiple uses. In the US, it was often called "Japanese knotweed" and was seen as a nuisance and difficult to eradicate. Willow and her group proposed the idea of having a conversation on why names mattered and the implications for using particular names, which they saw as similar to the difference between saying "corona virus" or "Chinese Virus" (Class Slides, April 1, 2021, Slide 63).

Felix and his partner discussed multiple places in their unit where a courageous conversation could be useful and appropriate. They noted affordances and constraints associated with different choices. For example, if they planned the courageous conversation for the first day of the unit, there would not be time for students to mentally prepare, but perhaps they could use the video on the importance to the Menominee People of the land slated for transformation into a pit mine. They thought that perhaps they could ask students to watch this video with guided questions to support students in thinking more carefully about the impact of the mine on the river and forestry, rather than becoming a debate about the rights of the mining company versus the rights of the Menominee People.

Alice. Alice recognized that courageous conversation topics would come up in her classroom and that it was important to address these topics and also to be attentive to what was

most helpful for her students. She was concerned about trying to have these kinds of conversations in her classroom as, “they’re difficult to plan for and it’s hard to predict student reactions and responses,” (Alice, Weekly Reflection Journal, April 2, 2021).

Alice focused on the courageous conversations that would occur in response to events outside the classroom and did not reflect on courageous conversations as part of her planned lessons/units. This aligned with Alice’s framework of science which included a claim about the separation of science and the sociopolitical. Sociopolitical issues could be addressed in her classroom, but they were not integrated into science, they were separate. Alice focused on the idea that sometimes if all teachers tried, “to have a courageous conversation on the same topic with students. This sounds exhausting for the teachers and the students,” (Alice, Weekly Reflection Journal, April 1, 2021). She drew from a personal experience of tutoring a student who shared that at one point in the Fall, “almost every teacher initiated the same type of courageous conversation and by the end of the week the student and her friends were exhausted and overwhelmed,” (Alice, Weekly Reflection Journal, April 1, 2021).

In response to this student’s experience and her own discomfort with facilitating this type of conversation, Alice concluded that because the student “wanted to get back to ‘normal learning’ as a distraction from everything….it will be important to communicate with colleagues when planning courageous conversation, so as to avoid burnout among students,” (Alice, Weekly Reflection Journal, April 1, 2021). Alice expressed concern for the ways students were responding to these conversations and what students were getting from participating in these conversations. This aligned with Alice’s framework of teaching in which part of teaching required caring about and valuing students’ individual experiences and ideas.

Alice's proposed solution was to assign one teacher, such as a homeroom teacher, to have this conversation with students so students were not having the same conversation all day. This would be a reasonable solution if the issue is simply that students were talking about the same issue all day. This requires an assumption that the problem was that students were being asked to discuss the issue too much, when perhaps the problem was that students were not being given a useful way to discuss the issue. Part of courageous conversations involves providing students with a way to take some action to address the issue. If there is no way to address the issue, the conversation can feel pointless and leave students feeling helpless and wanting a way to "get back to 'normal learning' as a distraction". Alice thought that the topics that necessitated these kinds of conversations were inevitable, but that having the conversation in her class was not necessarily the best course of action. She drew on the part of her teaching framework based in care of students' and their individual experiences as well as the part of her science framework that separated science from the sociopolitical to come up with a solution in which another teacher would facilitate these conversations as a way to not overwhelm students and leave science class free for "normal learning".

Willow. Willow described courageous conversations as "necessary in any classroom. Without them, you are a passive participant in the dominant culture of racism, sexism, homophobia, and any other issue that is hurting students." (Willow, Weekly Reflection Journal, April 1, 2021). Willow saw not having courageous conversations as perpetuating racism, sexism, and homophobia. Courageous conversations were a way to challenge harmful ways of thinking and acting that were treated as the norm. She stated that she "definitely plan[ned] on incorporating them in my teaching," and that "I think I need to do lots of research and educate myself to ensure that I'm structuring these conversations that aren't even further damaging to

some students," (Willow, Weekly Reflection Journal, April 1, 2021). Willow planned to incorporate these kinds of conversations into her classroom and was committed to seeking out information that would help her support her students in having these conversations in constructive, rather than harmful ways. She recognized that this would require a great deal of work on her part and that this work was in service of preventing further harm for her students. To Willow, not having these conversations was also a form of harm for her students. Her choice was to not have the conversations and definitely support harm or to have the conversations and work hard to minimize possible harm.

Willow continued in her reflection to consider practical ways to mitigate possible harms. She thought about the ways we (instructors) had divided people up into groups in the model courageous conversation and was concerned that students with harmful views might jump immediately into open discussion. She considered possible solutions to this, one of which was to do a survey before discussions to surface student views and consider what to do to prevent any harmful views from being shared unexpectedly with the whole class. She thought that perhaps she could "assign different groups different 'jobs' and group students based on the results of the survey?" (Willow, Weekly Reflection Journal, April 1, 2021). Willow immediately took up the idea of facilitating courageous conversations as something she would do in her classroom and started thinking of practical ways to implement them that would be most helpful and least harmful for her students.

Willow was already looking for ways to support students in thinking through ideas from multiple perspectives and dealing with the sociopolitical in science, as indicated by her frameworks of science and teaching. From the beginning of Methods Class, Willow had identified the sociopolitical in science, such as in her initial Science Story, she included,

"Science isn't perfect, and it isn't above human bias like I previously thought. If anything racism, sexism, and some of the worst part of humanity have been ingrained in science throughout history." (Willow, Science Story, September 21, 2021), so the courageous conversation was easy for her to take up and fit within her frameworks of science and teaching.

Felix. Felix, like Willow, stated that, "courageous conversations will become an integral part of my classroom. Preparation for such conversations is necessary as they will happen regardless of my desire for them to be or not, I therefore must embrace those conversations in ways which promote learning and a safe environment," (Felix, Weekly Reflection Journal, April 2, 2021). Similar to Alice, Felix saw courageous conversations as inevitable. Rather than worrying that these conversations would be difficult to plan for, as Alice did, Felix, like Willow, focused on the preparation that he could do. Felix continued in his reflection, "I have realized that you cannot control what students say, but teachers can take steps to decrease the probability that students will inflict and receive harm through classroom discussions," (Felix, Weekly Reflection Journal, April 2, 2021). Felix reflected on courageous conversations as integral to his classroom and focused on classroom discussions in general as places where students could inflict or receive harm, thus identifying classroom discussions in general as potential sites of courageous conversations.

This was perhaps at the forefront of Felix's mind having just completed his group's Macroteach during which a planned class discussion surfaced harmful stereotypes of Native American people. At the time, Felix and his fellow Macroteachers did not notice the comments or identify them as harmful as they were not familiar with the particular stereotypes as stereotypes. As we (instructors and Macroteachers) discussed the issue and what to do about it, it became clear that Felix wanted to talk about this issue immediately with the students (fellow

PSTs), but did not have a plan as to how to facilitate this conversation. I cautioned Felix against starting this conversation without a plan to mitigate harm and make sure the students who made the comments would be more likely to participate than have a defensive reaction.

As Felix reflected in an interview the summer after Methods Class:

> I just remember someone typed something on a public board or whatever. And then you guys [instructors] …basically stopped the macroteach and I didn't know why and I still, like, I struggled with understanding the severity of what had happened.… I remember being adamant about just talking to you about it in front of the class. And then you push back…and you're just like, 'How- how would you talk about it?' [I] was like, 'Well, I don't know. You just talk about it.'.... I…had not realized that …by doing that, I'd be rolling the dice on some people's well-being and and that's still a thought that I'm very uncomfortable with…. I'm not okay with rolling the dice on a conversation which has the power to inflict a lot of pain on some people…. I didn't know. I wouldn't have known if we hadn't done that topic. (Felix, personal communication, July 23, 2021)

This experience was likely on Felix's mind as he thought about courageous conversations and how they related to his teaching. This experience during his group's Macroteach and the subsequent class activity focused on how and why to facilitate courageous conversations helped Felix think through the ways sociopolitical issues could show up in the classroom in ways that he not only had not anticipated, but did not recognize because he had not considered sociopolitical factors when planning the unit, even though he knew the phenomenon was politically charged. Felix initially pushed hard to discuss the incident immediately, but upon further reflection, he realized that having that kind of conversation without preparation on his part would be irresponsible and potentially harmful to students.

Felix shared that he would not have learned this lesson if he had not taught using this phenomenon during his Macroteach and later, when asked if he would use the same phenomenon again, he stated emphatically that he would as it was a great, very generative phenomenon, but he would be better prepared for these sociopolitical elements of the phenomenon. Felix named

several steps he had learned through the model courageous conversation which he could take to mitigate harm, “a survey to understand perspectives students are bringing to the classroom, providing students with a warning about what topics would be discussed and how those conversations can be emotionally/harmful to allow students to prepare for those conversations mentally. Also providing students with resources to gain knowledge and evidence before conversations, evidence which could possibly challenge common alternative conceptions about that topic prior to conversations,” (Felix, Weekly Reflection Journal, April 2, 2021). After his Macroteach experience and the model courageous conversation, Felix identified several practical ways to facilitate conversations of sociopolitical issues in science class in ways that would mitigate harm.

These ideas of purposefully integrating discussions of sociopolitical issues in his science classes and taking steps to mitigate harm in these discussions aligned with and supported Felix’s frameworks of science as socially and culturally constructed and teaching as a way to support students in questioning the status quo.

DISCUSSION

In Methods Class, we started with a basic assumption that science teachers should teach in justice-oriented ways (i.e., in ways that assume the rightful presence of everyone in class, that science is cultural, social, political, and historical, and that science teachers should address the social, cultural, political and historical nature of science and of schooling in ways that support students in better understanding and using science in their own contexts). This goal was in line with what Calabrese Barton (2000) called for with multicultural science education and what, more recently, Mensah and Jackson (2018) have described as necessary in science teacher preparation. Teacher educators must prepare novice science teachers in ways that break the cycle of science schooling which excludes people, particularly girls and people of Color from science by treating Eurocentric, masculine ways of knowing and doing as universal scientific knowledge (Mensah & Jackson, 2018; Le & Matias, 2019).

The ways PSTs articulated, questioned, and revised their frameworks of science and teaching in the context of our Methods Class highlighted the complex nature of teacher preparation and the tensions inherent in taking up a justice-oriented approach to teaching in Methods Class while working to prepare PSTs to teach in justice-oriented ways themselves.

PSTs' Frameworks Revisions and Supportive Methods Class Activities

In answer to research question 1 of how PSTs articulated and revised their frameworks of science and teaching across Methods Class, I found that all PSTs clearly articulated, questioned, and revised their frameworks of science and teaching. My three focal PSTs represented final frameworks of science on either end of the spectrum (from universal to plural) and one more in the middle. Alice strengthened her framework of science as universal; Willow reinforced and clarified her framework of science as plural and contextual, and Felix shifted his framework of

science from universal to pluralist and contextual. All PSTs shifted their frameworks of teaching from teacher-centered to more student-centered. In answer to research question 2 of what opportunities in Methods Class supported PSTs in questioning and revising their frameworks of science and teaching, I found that the following types of activities were key in supporting PSTs in questioning their frameworks of science and teaching. These activities were those that presented science as cultural, that provided opportunities for PSTs to expand their ideas of what counted as success in science class, and that explicitly connected sociopolitical issues with science and teaching.

The Importance of Frameworks in Teacher Preparation

The work of preparing PSTs to become justice-oriented science teachers was complex and different PSTs took up the structure, pedagogy, and activities of Methods Class in different ways based on their ideas and prior experiences.

While teacher preparation programs provide PSTs with instruction in particular teaching practices aligned with theory, often these novice teachers abandon those practices when they begin teaching in their school contexts. Thompson et al. (2013) determined in their study of their teacher preparation program graduates that in their early career teaching, those teachers who had clearly defined frameworks of science teaching took up the teaching practices from their preparation program in innovative ways that fit their school contexts. Those teachers who had vaguely defined frameworks of science teaching enacted teaching practices from their preparation program in compartmentalized ways alongside practices common in their school contexts. Those teachers who did not have a defined framework of science teaching did not take up the teaching practices from their teacher preparation program at all. This study indicated the

importance of frameworks for teachers as they decide on their teaching practices in their varied school contexts (Thompson et al., 2013).

Revising Frameworks through Gee's (2016) Frameworks Discourse Analysis

In this study, I operationalized Gee's (2016) Framework Discourse Analysis process in my Methods Class to support PSTs in clearly defining their frameworks of science and teaching. We (instructors) designed Methods Class to support PSTs to: 1) articulate their frameworks of science and teaching (Science Story), 2) critically discuss their own and others' frameworks (class activities), and 3) reflect on and revise their frameworks of science and teaching (integrating class activities into Science Story). This study confirmed the importance of sustained critical self-reflection, in particular with regard to ontologies and epistemologies in science and teaching (Carter Andrews et al., 2019) in conjunction with a variety of activities designed to raise critical consciousness, all done within a broader assignment (the Science Story) in which PSTs actively and critically integrated ideas from multiple frameworks into their existing frameworks.

We (instructors) designed the structure, pedagogy, and activities of Methods Class to support PSTs in deepening their understanding of their own and others' frameworks of science and teaching with the goal of PSTs' developing justice-oriented frameworks and teaching practice. We followed my operationalization of Gee's (2016) Frameworks Discourse Analysis (FDA) which consisted of supporting PSTs in going through three steps in an iterative way: 1) articulating their frameworks, 2) critically discussing multiple frameworks, and 3) reflecting on their own and others' frameworks and revising their own frameworks. We drew on the work of other teacher educators and scholars who have studied pedagogies and activities that supported PSTs in raising their critical consciousness (Carter Andrews et al., 2019; Matias, 2013; Mensah

& Jackson, 2018), understanding their whiteness (Matias, 2013), and connecting theory with teaching practice (Thompson et al., 2013; Kavanagh & Danielson, 2020).

We utilized a version of the critical autobiography, which is commonly used to support PSTs in thinking about the ways social, cultural, historical, and political contexts have shaped their opportunities and ideas (Carter Andrews et al., 2019). We called this assignment the Science Story and we asked PSTs to focus specifically on their relationship with and ideas of science and teaching. The Science Story was intentionally left open so PSTs could choose the form which would best support their expression and processing of their ideas and experiences related to science and teaching, which is part of valuing and including multiple ontologies and epistemologies (Carter Andrews et al., 2019). We (instructors) also designed activities to support PSTs in critically discussing multiple frameworks of science and teaching. In these activities, we included some content that evoked emotion and a human connection between PSTs and the students, teachers, and communities to remind PSTs that interactions with science and school involve feeling human beings (Matias, 2013). We also included multiple narratives (Matias, 2013) and pushed beyond binaries and surface-level thinking to ask why systems and practices existed as they did and how these were connected to complex historical, political, cultural, and social values and practices (Carter Andrews et al., 2019). In these ways, our class activities were designed to support PST critical consciousness raising and critical discussion in ways that other scholars had documented as effective.

Our focus on deepening understanding of frameworks through Frameworks Discourse Analysis (FDA) (Gee, 2016) meant that we used these activities differently from other classes with a goal to raise critical consciousness. Because our goal was to deepen understanding of our own and others' frameworks of science and teaching and we worked to do this through the three

parts of FDA that I had posited, we used the critical autobiography as a working artifact to be used to articulate and revise frameworks. The assignments in class designed to raise critical consciousness provided new ideas and experiences PSTs could consider in their active reflection on and revision of their own frameworks as expressed in their Science Story. Because we (instructors) introduced the Science Story as a tool for expressing and working on our own and others' ideas toward deeper understanding, this assignment became more than a single assignment, but a way for students to make meaning of their past experiences and ideas in conversation with their current ideas and experiences during Methods Class. This structure of scaffolding the creation and revision of multiple editions of the Science Story based on integration of ideas and experiences from Methods Class supported PSTs in actively creating meaning from the multiple frameworks they worked with in class and intentionally revising their frameworks to incorporate how they thought about the variety of ways of being/knowing/doing they encountered during Methods Class. This active, iterative process of reflection on the critical consciousness raising activities in class and subsequent revision of personal frameworks of science and teaching was effective in supporting PSTs in more clearly articulating and nuancing their frameworks of science and teaching.

A Missed Opportunity to Address Whiteness in Science Education

One of the major regrets that I have about the ways we designed and implemented Methods Class was that we did not explicitly name and address Whiteness sufficiently. I had begun working with a group focused on Critical Whiteness Studies in the summer of 2020 and was aware of the importance of this work, but had not done enough of my own work to adequately incorporate this into Methods Class. Looking back on the class, I can see how toward the end of the Fall semester when students were thinking about culture in classrooms and in

science, that being able to name Whiteness and consider how Whiteness shaped the science knowledge and practices, as well as classroom norms with which PSTs were familiar would have been incredibly helpful for them in making sense of normalized expectations in school science. I, as a teacher educator, needed to have had more time and support thinking about how to explicitly discuss Whiteness in science and schools with my PSTs. As Matias (2013) clearly established in her work, this recognition and understanding of how Whiteness has been created and maintained to the harm of everyone, is essential for PSTs, and I would add, for teacher educators as well. This work of addressing and decentering Whiteness should be something all teacher educators are equipped to do, not just the teacher educators of Color who take on this work out of love for and a need to protect students of Color from well-meaning White teachers who would perpetuate racial injustice through our ignorance.

A Crucial Framework for Justice-oriented Science Teaching

It is important to note that in operationalizing Gee's (2016) Frameworks Discourse Analysis (FDA) in Methods Class with PSTs, the goal was not to lead PSTs to take up one particular, "correct" framework of science and/or teaching. Instead, the goal was to support PSTs in deepening their understanding of their own and others' frameworks through a process of repeated and iterative articulation, reflection, and revision of frameworks.

This focus on frameworks and our (instructors') adherence to Gee's (2016) and an asset-based (Tuck, 2009), rightful presence focused (Calabrese Barton & Tan, 2019, 2020) approach supported PSTs in articulating their frameworks of science and teaching more clearly and with greater detail in supporting evidence across Methods Class. All PST participants mentioned at some point that being asked to share and consider their ideas with the purpose of personal understanding and without instructors telling them which ideas were right or wrong, was

important for their deepened understanding of their own ideas of science and teaching. Through this focus on sharing and discussing frameworks with the goal of deepening understanding, all PSTs articulated, questioned, and revised their frameworks over the course of Methods Class. This did not necessarily mean that all PSTs articulated and revised their frameworks of science and teaching to support a justice-oriented science teaching approach.

While I focused on evidence of pluralist or universalist frameworks of science, this was not a focus on one particular "correct" framework of science, but rather on evidence of actively engaging in the process of trying to understand multiple ways of being/knowing/doing in science so as to deepen understanding of your own and others' frameworks. A universalist framework of science is evidence of only valuing one particular set of knowledge and practices in science and treating that set of knowledge and practices as neutral and "settled". This kind of universalist framework of science represents an unwillingness to consider that science is contextual and cultural, which means there are multiple frameworks of science to consider based on context and culture. Therefore, when I looked for evidence of pluralist frameworks of science, I was not looking for one specific "correct" framework of what science is, but rather for a more process-oriented framework, similar to Gee's (2016) "interpreter's framework" which he claims is necessary to adopt in order to productively engage with others' frameworks. A pluralist framework of science, much like an interpreter's framework, is a framework that includes claims about the existence and validity of multiple ways of being/knowing/doing in the world broadly and in science specifically. If PSTs do not take up a pluralist framework of science, this is evidence that they do not recognize or have an open mind to considering ways of being/knowing/doing outside their own framework.

While I was not trying to make PSTs take up a particular framework of the kind of science that is valid, I was looking for a framework of science that allowed for the consideration and serious reflection on multiple ways of being/knowing/doing in science. For example, in Felix's framework of science throughout much of Methods Class, he included one or more claims about the appropriate way for scientific knowledge to be communicated (e.g., in written form using the third person to make explicit statements), but during the Critical Friends Group reflection on the assessment (poster) he used during his Macroteach, Felix noted that there were multiple ways that his students/peers had expressed their knowledge of the focal phenomenon. Rather than immediately drawing from his framework of science (communication) and deciding these students/peers were incorrect and did not know how to communicate scientifically, Felix drew on his pluralist framework of science to ask himself and his peers what they were trying to communicate and to consider why they had chosen their particular form of language to do so. Felix then questioned why he thought science could only be communicated in one particular way and the affordances of using different language and representations in science communication. In Methods Class, we (instructors) did not try to convince PSTs to, for example, incorporate a particular claim into their science framework about the kind of language that could be deemed scientific. Instead, we worked to support PSTs to take up a pluralistic science framework that would support them in asking why something unfamiliar to them was done the way it was and determining how this new way of being/knowing/doing might be incorporated into their framework of science.

I will not presume to decide who should or should not move on in teacher preparation programs to become a teacher based solely on their participation in my class or their frameworks of science and/or teaching, but I will say that going through FDA and being able and willing to

articulate your own frameworks, consider those of others, and reflect on and revise your frameworks in light of what you have learned is a crucial process for any teacher, especially if we want teachers to develop justice-oriented teaching practice.

Importance of Programmatic Commitments to Justice-oriented Teacher Preparation

Methods Class was useful for supporting PSTs in expanding on and applying notions they already had about the cultural nature of science and the need for more inclusive science teaching. Some PSTs need more or different supports based on the ideas and experiences they bring to Methods Class. All of the PST participants, except Alice, discussed experiences outside of Methods Class that exposed them to ideas of science specifically as shaped by humans and tied to contexts of those humans.

Alice seemed to have a universalist science framework that she clung to by the end of Methods Class. This is something for teacher educators to be aware of so we can consider how best to support Alice in considering the constraints of relying solely on the science knowledge and practices she has encountered in textbooks and the affordances of expanding beyond this textbook knowledge. Alice recognized that other ways of describing and explaining the world existed, but did not see the importance of including those knowledges when she could simply select the textbook information. As stated previously, this combination of caring about student ideas and believing she had an obligation to get students to the factual truths of science as presented in the textbook was a recipe for assimilationist teaching (Mutegi, 2011, 2013). Even as students felt they were being listened to by their teacher, they would be directed to the one correct way of thinking about the world. As this one correct set of scientific ideas were generated by primarily European and European-American cishetero men, treating this knowledge as

universal knowledge upholds white supremacy and heteropatriarchy (Calabrese Barton, 2000; Mutegi, 2011; Bang et al., 2012).

Alice, and other teachers like her, may express and rely on frameworks of teaching that could support justice-oriented teaching, but when combined with a universalist framework of science, justice-oriented teaching seems unlikely. This does not mean that Alice could not go on to become a justice-oriented science teacher, but that Alice, and other PSTs like her, needed more support. Teacher educators might better support Alice in exploring how including these knowledges could strengthen her classroom and her own and her students' science knowledge and practices. Really, Alice's determination to maintain a universalist science framework speaks to the importance of introducing the idea of science as cultural and contextual in courses outside of Methods Class.

Methods Class can be designed to include activities that support PSTs to build on ideas they bring to class of science as done and shaped by humans and the social, political, historical, and cultural nature of science. It seems especially important to have at least one science class or lab experience that is explicit and open about the ways humans make decisions in and shape science. It is even better if the ways social, political, historical, and cultural contexts influence science are discussed in the class and/or lab experience. Alice did not have an experience like this and she struggled to consider that science was shaped by humans and also changed as people examined new evidence or ways of interpreting that evidence, let alone that this evidence, interpretations, and resulting knowledge could be shaped by cultural, social, political, and historical contexts.

I suspect that PSTs have an easier time developing a pluralist science framework when they have encountered the idea of science as cultural and contextual in their science classes both

in college and K-12 classes. If we want to prepare justice-oriented science teachers, it could be important to consider what kinds of science classes our PSTs are taking and the messages they are getting about what science is. Willow took a history and philosophy of science course as part of her degree requirements which focused on historical and social contexts of science. She also took the science course with Dr. Frizzle in which science was explained as shaped by the decisions of scientists. Felix took Chemistry courses that focused on student ideas and the importance of each individual student creating their own knowledge. Alice, in contrast, took classes that, while interesting, she described as unwelcoming to her questions, thus communicating that to be successful in university science, students must unquestioningly take in the information given by the professor. These messages about what science is within science classes mattered for PSTs' science frameworks and which ideas regarding science that PSTs were prepared to take up in Methods Class. An important step for preparing justice-oriented science teachers could be ensuring that the science classes at the university be taught in ways that acknowledge the ways humans shape science. As other scholars have called for in their work, this points to the need for preparing justice-oriented teachers to be a programmatic endeavor rather than the purview of one class (Sleeter, 2017; Carter Andrews et al., 2019).

CONCLUSION

PSTs left Methods Class with clearly articulated frameworks of science and teaching which were made visible through sustained critical self-reflection in their Science Story and Weekly Reflection Journal entries. Making their ideas/expectations of science and teaching and the experiences and assumptions that had shaped these ideas/expectations supported PSTs in reflecting on and revising their frameworks of science and teaching. Articulating how they developed their ideas/expectations of what science and teaching were, what it meant to do science and to teach, and who could do science and teach PSTs identified the experiences and assumptions that supported their current frameworks of science and teaching. Through sharing their frameworks with peers and instructors, PSTs also engaged with frameworks similar to and different from their own, supporting them in both questioning their frameworks and recognizing that multiple valid frameworks of science and teaching existed. Both frameworks of science and teaching were important for developing and explicitly articulating a framework of science teaching. For some PSTs, focusing on science as plural and contextual provided a helpful entry point for considering a purpose of science teaching beyond communicating particular cultural knowledge as neutral, objective and the only science knowledge. For other PSTs, focusing on teaching as supporting student sensemaking and engagement with multiple ideas and perspectives was a helpful entry point, but if the framework of science remained a universalist framework, this made it difficult to reconcile the science and teaching frameworks.

To support PSTs in recognizing, questioning, and disrupting oppressive structures and systems in science and schooling, in Methods Class, we focused on making the cultural and sociopolitical nature of science and teaching explicit. PSTs took up these activities in different ways related to their ideas, experiences, and contexts. When PSTs had been exposed to particular

ideas previously, such as the forms that racism can take in society, schools, and science, they were more likely to recognize racism in particular interactions in education. When these particular oppressions had not been made explicit for PSTs previously, they had difficulty stating why a particular interaction was anything other than just generally uncomfortable and something to be avoided. This indicated the importance of explicitly naming and explaining the ways oppressive structures and systems can shape everyday interactions and the importance of multiple opportunities, within and beyond Methods Class, to recognize and discuss the ways white supremacy, heteropatriarchy, and settler colonialism shape interactions and interpretations of interactions in science and school.

Lingering Questions

While I was not explicitly looking for particular school experiences that addressed science as a human endeavor grounded in social, cultural, and historical contexts, every PST who shared one or more of these experiences, started with or shifted toward a more pluralist, contextual framework of science. A possible question to consider is the relationship between the types of science classes and experiences PSTs have and their propensity for welcoming multiple ways of knowing and doing in their science classes. What kinds of science classes and experiences should be included in PSTs' teacher preparation program?

Another lingering question I am left with is related to the ways PSTs are recruited and assessed in teacher preparation programs. If we know that some PSTs are more likely to articulate and develop a more justice-oriented science teaching framework than others, what does this mean for how we recruit pre-service science teachers? What does this mean for the requirements we rely on to determine if a PST is ready to leave the program and become a teacher? What is it like to think about science teaching as inherently social, political, cultural,

and historical when science is often positioned as none of those things? What would it look like for teacher preparation programs to recruit PSTs who already think about science in a pluralist, contextualized way and already think about teaching as facilitating student sensemaking in ways that value multiple ways of knowing and doing?

Finally, for teacher educators who would like to teach in more justice-oriented ways or teacher preparation programs committed to justice-oriented teaching, what would it look like to provide supports for these teacher educators to critically reflect on their own frameworks of science and teaching? Perhaps, teacher educators could create, share, and revise their own Science Story. This way, these teacher educators would have clearly articulated frameworks of science and of teaching before working with PSTs to articulate, question, and revise their own frameworks. During this process of articulating, sharing, questioning, and revising their own frameworks of science and teaching, teacher educators could be supported to explicitly identify ways their own social, cultural, historical, and political contexts have shaped their frameworks, as well as what the implications of this are for the ways they teach and the expectations they have of students and the purpose of schooling. The goal would be for teacher educators to recognize and explicitly identify how our ways of knowing and doing are contextually-derived and that leaving these contexts implicit allows for normalized ways of knowing and doing to remain "neutral" and "normal" while all other ways of knowing and doing, and the people who engage in them, are treated as less than and needing to assimilate. Leaving implicit this normalized hierarchy of ways of knowing and doing, which currently supports white supremacy, heteropatriarchy, and settler colonialism, helps to perpetuate these oppressive structures/systems. Teacher educators should be supported in recognizing and questioning these oppressive norms and considering how teachers can disrupt these so they can disrupt these norms in their Methods

Classes and work with PSTs to identify and disrupt these oppressive norms in their future school contexts.

Personal Future Research and Teaching

In my future teaching, I plan to continue teaching Science Teaching Methods courses in ways that center sustained critical self-reflection related to science and teaching. This will include supporting consistent questioning of why we believe and act in the ways we do and working to make connections between individual ways of thinking and doing with broader social, cultural, political, and historical contexts. IN class, we will work to articulate why we want to teach, our goals and our students' goals might be and which teaching practices might best support working toward those goals. PSTs are typically familiar with teaching practices centered on control and information transmission. In class, we will work to question those practices and the outcomes they support and to consider different desired outcomes/goals (e.g., supporting student sensemaking and science that matters in their lives) and which teaching practices might best support those goals. I plan to draw from Ambitious Science Teaching (AST) practices as well as YESTEM justice-oriented science teaching practices to provide PSTs with examples and tools of justice-oriented science teaching practices.

Based on this study, in my future research, I plan to do a longitudinal study with my future science teaching methods class and students. In this study I will first focus on identifying PSTs' frameworks of science and teaching and how those have been articulated and revised over the course of Methods Class. I will also consider the types of teaching practices PSTs take up during peer teaching and in their field placement work. I plan to look at the relationship between PST frameworks of science and teaching and the ways PSTs plan for, implement, and reflect on lessons/units. Next, I plan to follow those PSTs into their first 1-3 years of teaching to observe

the kinds of practices they enact in their classroom and how those are related to their frameworks of science and teaching. I plan for this to be more of a participatory study in which these teachers and I reflect together on their teaching practices and frameworks and how they might be supported in enacting more justice-oriented teaching practices. I also plan to meet with students in my participant teachers' classrooms to learn how students are thinking about science and their experiences in their science class.

APPENDICES

Appendix A: My Science Story

In the following vignettes, I explore how each of these experiences shaped my conception of what science is and how I thought I, and later my students, should interact with science.

My Introduction to Science

When I was five years old, my dad was diagnosed with Amyotrophic Lateral Sclerosis (A.L.S.). To me this meant moving to California to live with my mom's parents where my dad spent his time in the La-Z-Boy recliner in the living room. He couldn't get up and he couldn't speak, but my little sister and I spent time with him watching TV, showing him drawings, and figuring out his birthday by pointing to months and days on a wall calendar and getting an almost imperceptible nod or headshake. I remember the day the first laptop computer came into our house. It had this amazing technology: text-to-speech. For a while, my dad didn't have the motor control to write, but he could use a pencil with a rubber stopper on the end to hit keys and the computer would speak for him. I thought that was the coolest thing ever! Technology was helping my dad speak again. This was what science meant to me; it meant improving people's lives.

I knew my dad was sick, but he seemed the same to me for a long time and technology was helping him do things the illness had taken away. I was very impressed by what scientists could do. I would ask my mom what was going to happen to my dad, especially after he went to stay at the hospital. My mom was studying to be a nurse at University of California, San Francisco (UCSF) and was taking part in medical research there. She would tell me that scientists were studying A.L.S. and you never knew, scientists do amazing things, maybe they would find a cure for my dad. So, I didn't worry too much about my dad. Scientists were on the job, if they could help him speak again, they would find a treatment or a cure.

One morning, my mom woke me up, not to get ready for school, but to tell me my dad had passed away that night. I didn't understand. The scientists were supposed to make him better; how could he die? My mom explained that he died before they could figure out exactly how A.L.S. worked and how to treat it, but they would keep working so maybe they could help other people in the future. I realized there was nothing scientists could do for my dad, but I didn't want anyone else to have to feel the way I was feeling. I decided that the job of scientist was very important. Being a scientist seemed like a tangible thing to do to deal with something that felt very much out of my control. But I could do what scientists did. I wanted to understand science, so I could study diseases, understand them, and treat them so other people didn't have to lose their family members to disease.

Learning How to Learn

Sometimes, when she had to, my mom would take me to her nursing school classes. I was fascinated. I would sit in the lecture hall with her and draw pictures of the organ system the class was learning about that day. I would ask my mom lots of questions about what she was studying and how the body worked. Sometimes she explained and sometimes she had a deadline. What I liked most was when she was studying for tests because she had a cassette tape with songs by "Too Live Nurse" that she used to study. "Too Live Nurse" wrote and sang medical parodies of popular songs, especially theme songs. "The Brady Heart" was a particular favorite that was a

play on The Brady Bunch theme song and all about bradycardia. I loved listening to the tape and hearing explanations of what they meant. I learned medical terms from my mom and thought this new language that allowed me to decode technical medical terms was so cool. I enjoyed being able to break down words and understand the condition they were describing. It was a code and I had parts of the key.

At this point, I loved learning how things worked and interacted with other things. I was also learning how to learn these things. The way to learn about science was through books and lectures, as I had seen through my mom's experiences in nursing school. I especially appreciated how, by understanding how things were supposed to work (e.g., a particular organ system), then, based on a person's symptoms, you could determine what was causing the problem and address it. This seemed so clear, logical, and simple, if you learned enough. It was clear to me that the thing to do was to learn everything that was known about the human body and how it worked. To me, it seemed that science consisted of a body of interesting and useful information about the human body and I wanted to learn it all. This conception of how to learn scientific concepts served me well in school science as well, even when the focus wasn't the human body.

Learning Science in School

In school, I also learned about ecosystems. These were also fascinating to me. They were like larger versions of the human body; they were living systems composed of multiple interacting parts and if you understood how the parts typically functioned, you could reason out what might happen if one or more parts changed in some way. This made perfect sense to me and was taught in a way that was personally relevant because it was place-based. My first exposure to this kind of science class, that I remember, was in Mr. Bradley's seventh grade science class. This was also the first time I saw science studied using experiences in addition to textbooks and lectures. In Mr. Bradley's class, we didn't just see pictures of organisms and read about them, we also went to the places these organisms lived and studied them up close. We got to experience the places and organisms we learned about in books firsthand.

In Mr. Bradley's class, we learned about different kinds of organisms, mainly the classes of animals and their different characteristics. We learned how naturalists closely observed and drew representative pictures of different organisms, partly because there weren't cameras and also because of the importance of the close observation required to accurately draw an organism, which helped naturalists better understand the organism's structure and functions. We too practiced careful observation and drawing of organisms. We looked at pictures in books, preserved specimens in jars, tiny organisms under the microscope, and inside organisms during dissections. We read about, observed, and discussed the structures, functions, habitats, and interactions of multiple organisms, especially those found on or near our school campus. We took fieldtrips to nearby wetlands and the San Francisco Bay and observed characteristics of the different habitats and what these told us about the organisms we saw or expected to see. Mr. Bradley took a boat and net out into the Bay and captured fish that he put in large plastic containers for us to look at up close before he released them back into the Bay. There were so many things to learn about the world around us and how all the parts fit together. I loved Mr. Bradley's class, which meant I loved science. And I was good at it. The information and ideas made sense to me. I studied, thought about, and remembered them. I looked forward to tests as ways to challenge myself and show what I understood and could figure out in order to answer the questions. These usually involved identification of organisms based on observed characteristics

or explanation of scenarios based on expected interactions. These ideas fit well with my conceptions of science and how to think about it; these interactions were already known, I just needed to learn them so I could interpret what I saw around me. This expanded my knowledge from the human body in isolation to the broader environment.

From School Science to Professional Science

As I moved on in science classes through high school and college, I felt that it was assumed I would become a doctor or medical research scientist. This is what I seemed to have been working toward from the time I was six years old and those were the only two science related careers that I was familiar with (besides Marine Biologist, which sounded cool, but the way people talked about it, it didn't sound like a job available to many people or that would have a great positive impact on people's lives). I loved science and I did well in my classes, but I wasn't sure I wanted to be a doctor. What I loved about science was that I could learn what people had figured out about how the world worked and I could apply that to improve my own understanding and to solve problems and figure out the answers to questions about phenomena. I could do this by reading about what experts in the field had already figured out and connecting this to my own experiences and questions. This is what school science taught me to do. Still, I enjoyed learning new things about how the world worked. I enjoyed structure and systematic study. I wanted to learn more about the human body so I could help people. And, I had been studying science for years, so if I wasn't going to be a doctor, it seemed obvious that I would become a medical researcher. In the summers after my junior and senior years of college, I applied for internships in two different labs studying cancer.

In the Lab

Both of my internship experiences took shape as apprenticeship experiences. I mostly stumbled my way into my first internship. I had taken a leave of absence from my university in the U.S. so I could study in Ireland for a semester. My dad was from Ireland and I wanted to know the place where he came from. I also wanted to get to know my dad's side of the family. During that semester, I focused on taking biology courses. Each course had a lab section and in one session, a guest scientist came in to teach us how to run two-dimensional electrophoresis gels to separate proteins. I thought this was interesting, as were all my lab experiences in Ireland, and I carefully followed the instructions to run the gels. I also asked questions of the guest scientist because I was interested. It turns out that she had an opening in her lab for the summer and she encouraged me to apply for a grant to work with her. I ended up staying in Ireland for the summer working one-on-one with Dr. Bernadette Moore in her proteomics lab. Bernadette was studying the proteins in cancerous and non-cancerous lung cells in order to find a mechanism by which these particular cells transformed from normal to cancerous. This cell line had not been studied this way before so the first thing we had to do was figure out the best way to run the gels to get the clearest separation of the proteins. Bernadette explained every step of the process in this study, showed me how to do each procedure, and observed and coached as I practiced and learned each new skill. I enjoyed learning all the skills necessary to conduct this research and appreciated that Bernadette talked through all the steps with me, not only to instruct me, but also to include me in her thought process as she made decisions. I felt I was getting a real, firsthand experience in what it was like to conduct scientific research, more specifically disease research. I enjoyed the systematic, logical approach to, not only finding answers to questions, but also how to go about finding those answers. It was also eye-opening to see how

Bernadette made so many decisions that determined how information would be collected. For example, as we were optimizing this procedure, Bernadette made decisions about the concentration of the solution and the length of time to run the electrophoresis to produce the clearest separation of proteins on the gels. Depending on these factors, different sized proteins would separate from each other and become visible as distinct spots on the gel. Bernadette's decisions determined which proteins would become visible as unique and what was good enough, in terms of making these distinctions between proteins. I was participating in the development of a research protocol rather than seeing protocols that had already been developed and accepted. I was realizing that all scientific instruments and procedures were created by someone. I was also thinking about how much I liked working with Bernadette, but I worried about how much she seemed to appreciate working with me because when I wasn't there, she worked in her sealed, clean room alone. Overall, I left Bernadette's lab feeling accomplished. I had learned a lot and, thanks to Bernadette's support, felt I could do scientific research if I wanted to pursue it, although I wasn't quite sure what the path was between college and becoming a researcher. Medical school seemed like a much clearer, more familiar path.

In my senior year of college, I had completed all my pre-med requirements and was set to apply to medical schools, but I wasn't sure I wanted to be a doctor. I still loved learning about the human body, how it worked, and how to fix things when they weren't working properly, but I wasn't sure I wanted to practice medicine. I just wanted to learn these things to know them, which didn't seem like an acceptable reason to go to medical school. Instead, I applied to the Peace Corps as a way to help people, travel, and have a two-year limit on this break from school and having to decide what my next step was. While I was waiting for my Peace Corps assignment, I applied for a summer internship at OncoMed Pharmaceuticals, Inc.

I began working with Dr. Lucia Beviglia on testing new cancer treatments in mice. This internship was also a one-on-one experience working directly with a primary investigator in her lab. I again had the privilege of learning all the parts of doing this kind of research from starting a study (getting new mice and injecting them with cancerous cells) to treating and monitoring the mice to ending a study (killing the mice and excising the tumors) to analyzing the final tumors and their cellular makeup. This work was also systematic and the logic behind the protocols was explained to me. The goal of the study was to determine how effective the company's new treatment was in comparison with the leading chemotherapy. In a way, this was another optimization study. In the proteomics lab, we were determining which procedure produced the clearest gels by running proteins through gels under specific conditions. In this lab we were determining which cancer treatment worked best in which quantities by injecting treatments into mice with tumors. A major difference was that in the first study we were running hundreds of gels, but in this current study, we were injecting and killing hundreds of mice. Both studies required careful, systematic testing, but it was harder to see that type of testing done on living creatures. While the work was interesting, and I learned many new technical skills, the job offer that came partway through the summer was easy to turn down because I did not want to spend my time hurting mice.

While I liked the structure of the kinds of experiments I had learned about in these lab experiences, I didn't know that I wanted to spend my life doing careful, systematic experiments to learn one thing. I enjoyed thinking about the big picture and how everything connected, rather than focusing in on one particular thing to the exclusion of all else. I wanted to learn the things

that others had found out, put those things together in a way that made sense to me to answer questions and explain phenomena, and communicate those ideas to others. I had practiced doing exactly this throughout school as I studied with friends or tutored. I loved making sense of ideas and communicating them to others in a way that made sense and was relevant to them. This was the part that was missing from the lab experiences, communication of findings to others, both within the research community and outside of it. It was a stroke of luck that when I joined the Peace Corps, I was assigned to be an Education rather than a Health Volunteer and I was sent to Mozambique to teach science.

Teaching Science in Mozambique

I am starting to see now that I was not taught science so I could contribute to science, but so I could read about and understand scientific knowledge and use it to explain the world. And that is what I tried to do for my students in Mozambique. My goal was for them to understand scientific ideas, how they explained phenomena, and to use these ideas to make sense of the world around them. I wanted them to question and reason through ideas rather than accepting them at face value without realizing that I was also asking them to accept certain information at face value. The basic scientific laws and principles we started with in class, from which students were to reason to understand the world, were still statements I expected students to take on faith as truth because that is how I saw them. These were facts and statements of truth based on the work of scientists. I had better understandings of the evidence behind some of these "truths" than others, but the primary reason for believing them was that I had learned they were true in science classes.

While I encouraged questioning and reasoning through ideas and problems, I did not question the framing underlying and shaping all these ideas, problems, and how they were named and thought about. I still had a conception of Science as the ultimate truth and correct way of understanding the reality of the world and how everything in it worked. I had seen how scientific knowledge was generated during the summer internships in research labs. I observed and talked through the development of research protocols based on the driving question, the available resources, and known methods of testing. One thing I learned was how all these tests and measures were created and decided upon by the scientist. This was the beginning of an inkling that scientific research is not completely objective and that tests, measurements, and experiment protocols all come from somewhere. They all come from people who developed them to study a particular question or phenomenon and this involved multiple judgment calls. While I had started to question what objectivity in science really meant, I still thought of science as objective and saw scientific ways of knowing as logical, supported by evidence, and open to adjustment based on the discovery of new evidence. I didn't realize that much of this evidence, the methods used to gather it, and the questions it answered were driven by cultural and social values and beliefs.

I encountered examples of the influence of cultural and social factors on scientific knowledge when I was teaching in Mozambique. I tried to teach science the way I believed it should be learned, as a systematic, objective way to make sense of the world. I believed that developing critical thinking skills was one of the most important things I could help my students do and that science provided a framework for engaging in critical thinking. I wanted my students to take scientific knowledge and use it to think logically and critically about claims they encountered in the world before believing those claims. This was particularly important when it came to claims about student nutrition and health, including sexual health. In class, we talked

about the reproductive system, bacteria and viruses, and sexually transmitted diseases. When students asked questions about claims they had heard about how diseases could and could not be transmitted and how they could be treated, I did not treat these ideas as claims, but as rumors to be dispelled with scientific knowledge. One instance of this stands out. A student told me that aloe vera could be used to treat gonorrhea. I dismissed this and walked her through how gonorrhea was caused by a type of bacteria, and that antibiotics killed bacteria and anyone with gonorrhea should be treated with antibiotics, not aloe vera. I did not consider where this information came from, the local knowledge about the antimicrobial properties of aloe vera and the difficulties accessing a doctor for a diagnosis and the antibiotics for treatment, whereas aloe vera could be grown and distributed by a local healer. I wanted students to understand what was being said about their body and proposed treatments when they went to see a doctor or healer so they could determine if the diagnosis and treatment made sense to them instead of simply obeying the authority figure. While I still think it is important to think critically and scientific ways of thinking can be a tool to do this, instead of adding to my students' set of tools, what I was actually doing was substituting my version of science as the authority. I did not realize that I was teaching my cultural way of knowing as *the* way of knowing.

I was privileging Western medicine and scientific ways of knowing over local cultural and traditional ways of knowing. I appreciated some of these ways of knowing, but only if they had been investigated and validated through Western scientific methods. I now believe that this way of thinking as a teacher was damaging and alienating. In this way, I reinforced the very thing I was trying to undermine; teaching students to believe what the authority figure said over their own thoughts, beliefs, and ideas, and that this was what it meant to learn in school. Many students employed the same defense mechanism with my class as they did in others where the teaching method was dictation with the expectation of exact memorization and regurgitation on quizzes and tests. They used what they "learned" in school for school and they used what they learned at home for life outside of school. Students would write beautiful explanations of causal mechanisms of disease and how to address them based on what we had learned in class. But if they got sick, they went to the healer and used traditional remedies. Students created a defensive divide between school knowledge and knowledge for life. This is not to say that I think all the consequences and outcomes of my teaching were negative, but this is one important area in which I believe I did harm. I could have done better if I had known better, but I had never explicitly seen these different ways of knowing positioned as part of science.

Teaching Science in the U.S.

The disconnect between my conception of what it meant to learn science and how my students thought about science and made sense of the world was also evident in my teaching when I returned to the United States, although I think this improved throughout my teaching. This is in part because one of the major barriers to learning in the school where I taught in the U.S. was that of language and I had some previous personal experience with culture shock and language barriers.

I was hired as a third-year teacher seven weeks into the fall semester at Mendota High School. Mendota is a small, rural farming town in the San Joaquin Valley of California. When I was hired, I was told that the school was made up of 88% emergent bilingual students. The primary language for most of my students was Spanish, but for a few, it was Arabic. Some of my students had been born in Mendota, some had come when they were small children, and some

had arrived that year. My classes were made up of a mix of students from those who only spoke English to those who only spoke Spanish or Arabic, and everything in between. For many of my students, my first concern was being able to communicate with them and their being able to communicate with each other. We all had to be able to do this if we were ever going to learn about science concepts. I broke out my rusty Spanish mixed with Portuguese to attempt to talk with my students who spoke only or primarily Spanish or who were mentally exhausted by trying to learn science concepts in a foreign language. The fact that my Spanish skills were rusty meant that my explanations may have been rough, but in some cases, this also helped some of my students to feel more confident and to try out their English with me one-on-one at first. If I could try my imperfect Spanish and struggle to find words and talk around them, it became ok for them to do the same in English. I found that if I could show vulnerability and be open about what I didn't know, it became a classroom norm that vulnerability was not only acceptable, but part of learning.

I also remembered what it was like to start school in a place where you didn't know the norms, but you were expected to. When my family moved to California from Bahrain, I "looked like an American," (if that is even really possible or meaningful), but I was a little white girl whose first language was English. It was assumed that I should understand what it meant to be in an American school, but this new American school was very different from the British school I had attended in Bahrain. For example, when I left my school in Bahrain, I was a great student and a good speller. I arrived in this new school and suddenly, I didn't know how to spell words. This was extra confusing because I knew these spellings to be correct, but my teacher would mark them wrong. No one explained to me that American and British English spellings are sometimes different, as are quite a few word meanings. This seems like a small thing, but it is only one example of how foundational things that I thought I knew suddenly were incorrect or did not apply in this new setting. I had to learn things all over again without understanding why what I knew didn't count anymore. This is what happens to many students when they come to schools with ideas and experiences that don't align with what the teacher/school system has deemed the normal, important ways to behave and the knowledge that is valid at school. My students left an environment where communicating in Spanish or Arabic was effective and the norm and when they crossed the boundary of the schoolyard/classroom, they entered a place where their language was seen as a barrier to learning. Those who spoke and wrote in English had an artificially created advantage. In order to learn, you first had to figure out how to speak, read, and write in English. What a ridiculous assumption. Learning and communication happen through any language. The limiting factor was the teacher and the teacher's ability to communicate. The method of communication along with the knowledge/ideas/experiences students entered the classroom with weren't wrong, weren't less important than the ideas and experiences promoted in the classroom, but it was the norm and it was easier to treat students' language and ideas as inferior and not belonging in the classroom than to adjust the expected curriculum or the teacher's/school's ways of doing things. This set up students to feel that their language and ideas and experiences didn't fit and weren't important, not only in the classroom, but in the country. To be successful, you must leave behind your ways of communicating and being in the world and take up the ways of the school...English, memorizing "facts", passing tests.

More recently than this experience, I had also been in Mozambique and when I arrived there, I did not speak Portuguese, nor was I familiar with the culture or the norms of the school

system. I remembered very well the frustration of being in an immersion class in which I could not understand a single word the teacher was saying and the embarrassment when she clearly looked directly at me and asked a question I could not understand let alone respond to. I remembered how helpful gestures, context, and drawings and symbols were in helping me put together clues as to the basic meaning of the lesson and the question. I also remember how essential it was to talk to fellow classmates in my first language to commiserate in our shared confusion, as well as attempt to puzzle out the class content together. This helped me feel that I was not alone in my confusion and frustration, that I was not stupid or inadequate, but that this was confusing and difficult, and we were in it together. I remembered these experiences and thought about how much harder this must be for many of my students who had not chosen to come to a country where they did not speak the language yet, who were teenagers who were already dealing with all the confusion, frustration, and embarrassment of adolescence, and who were so new to the school that they did not yet have understanding friends to commiserate with.

A large part of my teaching became about making my class accessible to all my students. This meant ensuring that all my class materials were available in English and Spanish. Unfortunately, I didn't have access to materials in Arabic or a way to translate them into Arabic and while I wish that I had learned some Arabic while I was in Bahrain, I lived in an English-speaking home and attended a British school. Greeting students was the extent of my Arabic language ability. Luckily for my students who spoke Arabic, they also spoke, read, and wrote in English, and had picked up some Spanish from Spanish-speaking friends. More than simply providing materials in English and Spanish, this meant setting up my classroom in strategic groups based on language skills, personality, and methods of engagement so that it became the norm to talk through ideas and assignments with each other, as well as to read together and break down texts together. When we learned new terms, I would share Latin roots that we could use as a class to decode the current science word, as well as future words. We also connected these words to the Spanish word, which, many times, had a similar root. Because the differences in language were so obvious, it was easier to see how to incorporate the idea of decoding science language into my classes. This decoding was something I had always enjoyed doing and using Latin roots and Spanish words to break down and understand science terms became a process everyone could contribute to and benefit from.

We also focused on the importance of explaining concepts in your own words and with examples that made sense to you. This was the way you knew you understood something. Anyone could use a big science word, but this didn't necessarily mean you knew what it meant or were using it correctly. We talked about the importance of communication; you could know everything about everything in the world, but if you couldn't explain it to anyone else, what was the point? This also meant that there was no one right way to explain a concept. You could explain using pictures. You could explain by telling a story. You could explain using an analogy. You could explain in writing or orally. You could use playdough or other modeling methods. You could explain in Spanish. You could explain in English. You could explain individually. You could explain with a partner. As long as you and your audience understood the concept, this counted as communication and understanding. The point was not to explain in a particular way, it was to understand concepts and communicate your understanding to others. I was not particularly good at this my first year teaching in Mendota, but as I got to know my students and thought explicitly about what my goal was as a science teacher, I realized that I didn't care if all my students could write a textbook perfect definition of a word or concept. This was not a useful

goal in terms of understanding and being able to apply science concepts, nor was it a reasonable or useful expectation of the majority of my students.

I noticed that when the expectation became understanding and explanation, my students worked together on explanations in more meaningful ways and many more of them became engaged as they saw how they could be successful. This was evident in all my classes, but my 7th period Integrated Science class provides a particularly clear example. This class was created by the administration to provide a science class for Juniors and Seniors who needed another science class to graduate, but would not be successful in the regular science classes (e.g., Biology and Chemistry). These were students who had received failing grades or barely passed Biology and administrators decided that Chemistry was too difficult for them. These students still needed a third science class to graduate, so the administration created "Integrated Science" a class based on the Integrated Science course taught at the middle school level. As a teacher, I was handed one middle school textbook titled Integrated Science and told to teach the class. There were not other expectations of requirements, I simply needed to give these students a passing science grade. This class was treated as the dumping ground for students who couldn't cut it in the "real" science classes and my students knew it. They came into class openly sharing that they hated science and/or they were not good at science. It turns out, what they hated was memorizing "facts" for the sake of regurgitating them on a test. The administration's low expectations for this class were a double-edged sword. They were insulting and demeaning for these students, but they also meant that we had a lot of freedom in this class. We spent the entire class doing science, not just memorizing parts of someone else's science. We explored chemical bonds and states of matter using models and observations and tests of the behaviors of ooblek (corn starch and water) Two of my students who were the most adamant in stating their hatred of science, stayed after class that day to continue their experiments with ooblek and the conditions that produced different behaviors. They were smiling and discussing their explanations and reasoning behind the observed behavior the entire time. That class was one of my favorite science classes to teach because we had the time to follow student interests and dive deep into how and why things worked the ways they did. We got to do actual science that students wanted to pursue because it was guided by their curiosity. The class of "problem" students who "couldn't succeed in science" was, in reality, a class of brilliant young people who thrived when they were supported in exploring and explaining the world in ways that were meaningful to them.

As I continued to try to follow this kind of science teaching, not only did my forms and strategies of instruction change, but so did my assessments. There were still written assignments and some written exams, but these were always given in the same language as the language of instruction and responses were explanation-based rather than requiring one word or multiple-choice responses. These written exams were not the primary form of assessment either. Instead, assessment was based on progress in and explanations of projects, group modeling, small group and whole class discussions and debates, and interpretations of class experiments where there was not one obvious correct answer. By my second year teaching, I scrapped the traditional 200 question multiple choice exam that had been passed on to me by the department and chose to spend the last month of class helping students work on inquiry projects individually or in pairs in which they investigated a question of their choosing on any topic that could be answered scientifically.

While my choice to change the end-of-year assessment was not initially a popular one in the Science Department, the attitude seemed to be that I would figure out that the multiple-choice test was a better option once I had to grade all the student projects at the end of the year. As my students started working on their projects, my colleagues started hearing about the interesting work students were doing. Students would want to share their projects with other teachers. My classroom was covered in materials used to create presentation boards to share their work. I had so much fun giving feedback and learning with my students that the process of facilitating and assessing this project was clearly much more fun than reviewing for, administering, and grading the multiple-choice exam. Two other factors helped in making this shift to a project-based exam. A new science teacher was hired and he came into the school with the goal of engaging kids who were typically pushed out by schools. He wanted to try a different kind of exam, so he tried the project assessment and he and his students had great success with it. In addition, there was administrative support because the NGSS was being introduced to our district and schools were looking for more project-based and inquiry-driven activities and assessments to align with the new standards. This project-based assessment fit well with the new requirements. Most importantly, I found this process to be a more meaningful way for me to evaluate the skills and knowledge my students were learning and using than any multiple-choice test. This project was one that got closer to valuing students' ways of looking at the world and what they cared about. The choice of topic was wide open. The question they chose to focus on in that topic was completely up to them, as long as it was something they could explore without harming themselves or others. Students came up with a plan as to how to investigate their topic and answer their question. They followed their plan and adjusted it as they encountered new information or practical issues. They chose the language in which they would report their topic, question, process, and findings and how they would present this information. They did need to have a written report of what they had done and found, as well as a visual representation of this and there were guidelines as to the kinds of things that might be included, but the content and form the visual representation took was up to the students. It was amazing to see my students get so excited about their projects and what they were learning. They talked to each other and learned about each other's projects. Students who would not speak in the beginning of the year were confidently presenting their findings to their classmates as experts.

This was much closer to treating science as a way of knowing and making sense of the world, as well as honoring the lived experiences and interests of my students. Being in a position in which I literally could not teach any version of science and students could not learn it until I thought about what my students' experiences, skills, and priorities were forced me to think explicitly about what the goals of science education were. Was the purpose to get students to provide definitions of terms in English to pass a test? If so, a good portion of my students were in an impossible position. But if the purpose was to help students make sense of the world around them using science concepts and explanations, that was possible. It just required figuring out how everyone in class could communicate with one another and express and listen to one another's ideas about how the world worked and how science ideas applied to students' experiences and interests.

One of the things I am realizing is how important it is to explicitly state your purpose in education and then to check everything that is done to see if it actually contributes to working toward that purpose or if it just seems to on the surface. I feel this was evident in my time teaching at Mendota High School, but it was problematic in Mozambique because while having

an explicit guiding purpose is important, it is not enough if you don't stop and question what your students think about this purpose, how their experiences and ways of knowing can enrich everyone's understanding and thinking, and where your own assumptions are as a teacher.

Appendix B: Pre-service Teacher Interview Questions

At the beginning of each interview, discuss the consent form and answer any questions. Explain to the interviewee that they can skip any question, can stop the interview at any time, and confirm that it's important to get all of their words so I hope it's OK to record the interview. The purpose of this interview is to talk through some moments from our Methods Class when I think you were recognizing, questioning, or consciously applying a framework to an activity in our class. The idea is to think together about how you are seeing frameworks that guide your ideas of science and science teaching in order to tell a story of you, your frameworks, your teaching, and how those were shaped, or not, during our Methods Class. Based on what we talk about today, I will write up a story of how we're both interpreting the moments from our class and your participation in them. I'll bring this story to you in our second interview session so we can check-in about how well you think I've described the moment and your experiences in our class.

Moments

Remind the PST of the moment I've brought to discuss with them. This could take the form of showing them an artifact or recounting a story of a moment in class to ask if they remember the event. Then ask the following:

1) What do you remember about this moment?
2) What did this moment mean to you at the time?
3) How are you thinking about this moment now?
4) I noticed that you mentioned [a particular framework or decision], would you talk about why you brought that up in this way?
    a. Where did this idea come from?
    b. How did that connect to your ideas about science or teaching?
    c. How did this connect to your teaching decisions?
5) I see this moment as connected to [recognition/questioning/consciously applying] a framework of [race/gender/religion/sexuality/etc.].
    a. Is that something you were thinking about in this moment?
    b. Is that something you would agree with looking back? Why or why not?
    c. Is there another moment that feels connected to this moment or framework for you?
        i. What is that moment?
        ii. How is it connected?

Other Ideas

1) What else would you like to talk about in relation to our class and frameworks of race, gender, sexuality, religion, and the nature of science, or the purpose of teaching?

Demographics

Would you share how you identify yourself in relation to these frameworks?

1) Race/ethnicity

2) Gender
3) Sexuality
4) Religion
5) Any other personal characteristic you feel is relevant

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