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Addressing the epistemic elephant in the room: Epistemic agency and the next generation science standards

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Abstract  
The Next Generation Science Standards (NGSS) [Achieve, Inc. [2013]] represent a broad consensus that teaching and learning expectations must change. Rather than memorizing and reciting information, students are now expected to engage in science practices to develop a deep understanding of core science ideas. While we want to share in the optimism about NGSS, the standards are not a silver bullet for transforming science classrooms. They are, instead, another reform document designed to suggest opportunities for students to actively engage in knowledge construction themselves—to be doers of science, rather than receivers of facts. A foundational contradiction underlies these efforts—while we want students to do science, we seem to mean that students should mimic practices others have selected as important to learn, and content others have selected as foundational. As a result, students are rarely positioned with epistemic agency: the power to shape the knowledge production and practices of a community [Stroupe [2014] Science Education 98:487–516]. We argue that unless the field tackles significant questions around precisely how students can be active agents in knowledge construction, we will likely continue to implement learning environments that position students as receivers of scientific facts and practices, even as classrooms adopt NGSS. In this conceptual analysis article, we unpack the construct of “epistemic agency” and its relationship to the NGSS, using a vignette to illustrate how students are typically positioned in researcher-developed curricula. The vignette, which describes a seventh-grade class exploring which of two lakes is more at risk for invasion by the spiny water flea, provides an
Ms. Adah’s seventh grade class faced a problem: Two small lakes in their community - Lake Aniwa and Lake Vilas - were at risk for invasion by the spiny water flea, a new resident of a Great Lake on the community’s border. Over the course of several weeks, students participated in a science unit designed around the potential spiny flea invasion, culminating in the engineering of a community-based solution to protect the lake students predict is more vulnerable. Since the unit was based on a local problem, the teacher hoped to capitalize on student experiences, and to pique interest and investment in their small Midwestern ship-building city. In addition, the teacher sought to capitalize on the rich opportunities for modeling provided by the spiny water flea’s unique life cycle and its role in biological invasion.

During the unit, students engaged in science practices, such as collecting data and obtaining information from numerous sources, including analyzing lake water samples and examining dead fish with the water flea in their gut. In addition, students used other resources, such as video and text, to compile information about the spiny water flea to understand its needs, including its dependence on Daphnia (small planktonic crustaceans), which in turn depend on algae. The students learned about the food web in the lakes, and determined that the spiny water flea compete with small native fish for food.

During one lesson in the middle of the unit, the students focused on how lakes are stratified by temperature, and how those layers change seasonally in different kinds of lakes. As temperature is such an important part of the spiny water flea’s life cycle, the students discussed whether this factor might influence the potential of spiny water flea invasion in one lake over the other. Students used bathymetric maps showing underwater topography and depth-to-groundwater maps; they found that Lake Aniwa was wide and shallow and fed by warmed surface water, and Lake Vilas was deep and fed by cold groundwater. Ms. Adah asked the students groups to model the movement of water particles, and to write an explanation of how the lakes’ temperature layers were affected by both the warming of the sun and water input flow.

Ms. Adah then shifted her students toward making tentative claims about which lake the spiny water flea was more likely to invade. She assigned some students the role of “claim-maker,” some to find connections between different claims, and some the role of “evidence-checker.” In the conversation that ensued, students shared their claims. They supported their claims with evidence from the investigations, the models, text-based resources, and their experiences in the lakes. The evidence checkers pressed claim-makers for evidence and indicated when they were satisfied. Ms. Adah recorded claims,
noted new questions, and began to help students plan investigations based on their proposed claims.

Next, Ms. Adah asked students to make connections between ideas. One student, Jamar, replied, “Pamela, Sofia and Kanye are all talking about temperature being the important thing for our prediction.” Aleena added, “Kanye and Harper both talked about food, too.” Then she said, “This isn’t a connection, but... Why would the spiny water flea like cold water best? It clones itself fast, every three weeks, in warm water. It doesn’t make sense, it should love warm water.” Ms. Adah replied, “First of all, we can’t really use the words prefers and likes, I think. Because we are talking about adaptation, not preferences.” She added, “Remember, adaptation matches the environment, you can never talk about one without the other. The spiny water flea is adapted to a certain kind environment. Let’s look at our descriptions of the two lakes again in our table groups. Is there anything about the harsher environment in Lake Vilas that would be beneficial to the spiny water flea?”

Students had several ideas, some of which Ms. Adah had not anticipated. For example, Kanye’s table thought that there might have just been cold lakes in Europe, and so the spiny water flea chose similarly hostile lakes in the U.S. Kanye said, “Maybe the spiny water flea just doesn’t know any better.” Ms. Adah nodded at Kanye, unsure what to do with his idea, and called on another group. This table group, which included Yessica and Juan Carlos, also brought up the spiny water flea’s native habitat. They planned to research if there were predators of spiny water fleas in European lakes, wondering if the water flea’s predators in Europe were a bigger threat in warm shallow waters. The class discussed this proposal at length. Was there a special predator in Europe that thrived on the crustacean?

Before class ended, Max also brought up an unexpected question, “How does light come into this?” Ms. Adah asked him to explain more. Max said, “Is light just the same as heat? And doesn’t it matter how far down it goes? Lake Aniwa has plants all across the bottom. We can see them. Since the Daphnia eat algae and the algae need sunlight, isn’t light a bigger deal than heat?” Ms. Adah told the class that she had not thought of Max’s question. She noted that light waves likely caused thermal energy, but such energy may not always relate to light. She then said, “This is a fantastic question that I need to think about. I am going to write it on the center of the top of the board so we come back to it. Talk to your tables, and then do a quick-write. What are your thoughts, how would light make a difference in the lakes? And what could we do, as a class community, to investigate this question?”

1 | INTRODUCTION

If educators and researchers were asked whether they want all science students to actively construct knowledge through participation in science, we suspect that nearly all would answer with a resounding “yes.” From as far back as Dewey (1916) and other progressive philosophers, science educators have expressed a desire to position students as constructors of knowledge and “doers” of science. Such educators also hope that students sense that their experiences, knowledge, and the ideas they construct are important—even consequential—for the learning that occurs in classrooms. The most recent push for students to know and do science, the Next Generation Science Standards (NGSS), calls for students to
participate in scientific practices as they make sense of deep and important scientific ideas (Achieve, Inc., 2013).

The vignette that begins this article depicts our understanding of the current consensus view of a learning environment that is consistent with the NGSS. As early and mid-career scholars whose work will largely take place in the era of NGSS implementation, we are excited to see the ways in which the NGSS could promote learning environments that position students as sense-makers and “doers” of science. For example, in an article describing modeling practice consistent with NGSS and the 2012 Framework for K-12 Science education, Krajcik and Merritt (2012) write:

> Often in class, students are given the final, canonical scientific model that scientists have developed over years, and little time is spent showing them the evidence for the model or allowing them to construct models...The Framework emphasizes that multiple models might explain a phenomenon and that students should improve models to fit new evidence” (p. 7, italics added).

Similarly, Schwarz, Passmore, and Reiser (2016, pp. 15–17) argue that implementing the NGSS will involve a shift from valuing only what students know to emphasizing students’ participation in addressing the following four questions: (i) What are we trying to figure out? (ii) How will we figure it out? (iii) How do we keep track of what we are figuring out?, and (iv) How does it all fit together? In sum, we see great potential for NGSS implementation to support the development of learning environments in which students take up epistemic agency—that is, environments in which students shape the knowledge and practices of their classroom community (Damsa, Kirschner, Andriessen, Erkens, & Sins, 2010; Scardamalia, 2002; Stroupe, 2014).

Despite their potential, the NGSS are not a silver bullet for transforming science classrooms. They, instead, come from a long history of reform documents that have sought to shift instruction in ways that engage students in knowledge construction—to position them as doers of science, rather than receivers of facts. We argue that, while the field has developed loose consensus views of student roles in knowledge building—views that drive the design of the standards—these descriptions remain under-theorized. Unless the field tackles significant questions around precisely how students can become active epistemic agents in knowledge construction, we will likely continue to create learning environments that position students as receivers of scientific facts and practices, even as districts adopt the goals and language of the NGSS. Therefore, we must explore questions such as:

- Whose ideas and contributions shape the classroom community’s shared knowledge construction work?
- Who will evaluate the ideas being constructed?
- Who decides which knowledge is relevant to the knowledge building?

This conceptual article explores the potential of the NGSS and demonstrates the under-theorization of issues related to students’ roles in knowledge construction by exploring ways in which a complacent enactment of the NGSS might limit students’ epistemic agency. By complacent, we mean that the enactment of the NGSS could appear to offer ways in which students might be positioned as, and perceive themselves as, epistemic agents, while actually positioning students as receivers of “correct” information and practices.

We begin by better defining “epistemic agency” as a construct that allows us to explore what it means for students to participate in meaningful scientific knowledge construction. We then unpack the complexities of designing and analyzing learning environments that afford epistemic agency, using the vignette that begins this article to problematize undertheorized aspects of consensus views that, we
argue, have important consequences for realizing the potential of the NGSS. We conclude by describing why struggling with our understanding of epistemic agency and its role in NGSS-aligned learning environments is important work that the field of science education must undertake.

2 | EPISTEMIC AGENCY

We use the construct of “epistemic agency” to explore the ways that students are able to meaningfully contribute to the knowledge and practices of a classroom community. Historically, the concept of agency is tied to a concept of “free will,” coming out of a “legal, ethical, moral and practical” need to assign responsibility for actions outside of contextual constraints (c.f., Matusov, von Duyke, & Kayumova, 2016, p. 422). More specifically, the term epistemic agency was introduced into education literature in relation to the research on knowledge-building communities conducted by Scardamalia and Bereiter (1991). In its simplest interpretation, epistemic agency refers to students’ ability to shape and evaluate knowledge and knowledge building practices in the classroom (Damsa et al., 2010; Scardamalia, 2002; Stroupe, 2014). Building off the legal notion of agency, epistemic agency involves assigning students responsibility for some knowledge building actions.

Scardamalia and Bereiter (1991) argue that attention to agency in classrooms follows naturally from education’s constructivist roots. When educators shift from treating students as acquirers of knowledge to active constructors of knowledge, we must critically consider how students (i) make choices in relation to knowledge construction and (ii) evaluate knowledge construction. Looking across the literature, students might have agency to set the goals for their learning, determine and evaluate processes for meeting those goals, and decide when goals have been fulfilled; for example, students might decide when they have developed a satisfactory explanation, model, or product (Bandura, 2006; Damsa et al., 2010; Scardamalia & Bereiter, 1991). From this individualistic perspective, we can contrast students’ and teachers’ agentic roles and responsibilities; that is, differentiating between those decisions and evaluative processes that are carried out by students, and those that are the responsibility of an institutionally recognized authority (e.g., teachers, administrators, and district-level coordinators and coaches) helps us characterize the ways in which students might be considered agentic.

Agency also appears in sociocultural literature, which locates human action in activity systems and explores how activity is constrained and enabled by social and physical structures and schema (Engeström & Sannino, 2010; Holland, Lachicotte, Skinner, & Cain, 1998). From this perspective, all science learning takes place within systems that include historically reified norms such as canonical scientific ideas, historical goals for learning, ways of sorting students, and even the structure of the school day (Carlone, Johnson, & Scott, 2015; Kane, 2015; Varelas, Settlage, & Mensah, 2015). Agency, then can be conceptualized as an actor’s ability to mobilize resources for their own goals, shape the systems that they are acting in (Varelas, Tucker-Raymond & Richards, 2015) and if necessary, disrupt structures and re-figure available resources (Dotson, 2014).

Consequently, determining whether authorities or structures “grant” agency is insufficient. First, numerous scholars have pointed out that, even in the most overtly controlled settings, students always have agency; for example, they decide whether to resist a teacher’s directions, whether to accept the content being taught as relevant, and whether to contest dominant ways of talking or thinking (Gresalfi, Martin, Hand, & Greeno, 2009; Hand, 2010). However, what differs across settings is what specific forms of agency are valued and made available, and for whom they are valued and made available. In addition, by affording and constraining goals and ways of acting, community structures impact students’ perceptions of the positions that they can, or want to, take up in the classroom community (Holland et al., 1998). This perspective suggests that attributing epistemic agency to students involves considering not only the specific ways in which students are positioned but also how they perceive,
co-construct, and take up positions (Arnold & Clarke, 2014). Therefore, we define epistemic agency as students being positioned with, perceiving, and acting on, opportunities to shape the knowledge building work in their classroom community. Furthermore, given the numerous ways in which students might act with epistemic agency, we argue that focusing on whether students in NGSS classrooms do or do not have agency is unhelpful; rather, we should seek to characterize the specific opportunities students have to perceive and act with the agency to contribute to knowledge building.

3 | OUR APPROACH TO INTERROGATING EPISTEMIC AGENCY AND THE NGSS

Given our definition of epistemic agency, we propose that understanding how to shift students’ roles in classrooms is a complex and multidimensional task. In this article, we examine four opportunities for students to be explicitly positioned with agency, perceive themselves as epistemically agentic, and to act with that agency:

1. Opportunities to solicit and build on student knowledge as a resource for learning
2. Opportunities to build knowledge
3. Opportunities to build a knowledge product that is useful to students
4. Opportunities to change structures that constrain and support action

In presenting this list, we do not claim that epistemic agency has four parts, or that only these four opportunities for epistemic agency exist in schooling. No doubt there are many more at a variety of grainsizes and levels. We also do not claim that the four listed here are mutually exclusive. Furthermore, we acknowledge that epistemic agency is a complex construct, and we choose to untangle it here for argument and analytic sake; these four opportunities are undoubtedly difficult (or impossible!) to disentangle in classroom practice.

Even with these caveats, we nonetheless choose to focus on these four opportunities because they have been salient in different ways in our own work with teachers and students in science classrooms. Additionally, as we describe in each section, we note that they have been the focus of some discussion and research in our field. We hope that other researchers will read our work, notice missed opportunities and conundrums, and subsequently explicate and elaborate those complications that are surfacing in their work. Only in that way, with multiple scholars from multiple perspectives looking at similar phenomena, can we begin to make progress toward meaningfully supporting students in actively constructing knowledge through participation in scientific sensemaking.

In the remainder of the article, we analyze these four opportunities for students being positioned with, perceiving, and acting with epistemic agency. For each opportunity, we use the vignette that began this article as a foundation for concepts and examples. First, we describe the literature that provides the basis for each opportunity for agency. Second, we discuss how the vignette illustrates ideas that are frequently mentioned in research and efforts to design curricula that enable students to construct and evaluate knowledge. Third, we interrogate the complications and contradictions that are invisible in the vignette, to illuminate assumptions that science educators might make about epistemic agency. Fourth, we describe a complacent approach to the NGSS—one that appears to shift students’ roles in knowledge building but would likely merely re-instantiate students’ positioning as receivers of correct information and practices. Finally, we pose questions that the field will need to address to more fully articulate a vision of epistemic agency that reflects the intentions of the NGSS and fosters “imagined possible futures” for science education (Calabrese Barton et al., 2013).
3.1 | Epistemic agency opportunity 1: soliciting and building on student knowledge as a resource for learning

Science education holds a consensus view that students’ understanding should be used as a productive resource in instruction (e.g., Campbell, Schwarz, & Windschitl, 2016; Hammer, Elby, Scherr, & Redish, 2005). Rather than treating students’ ideas as “misconceptions” that inhibit learning and must be replaced with correct explanations, the field increasingly positions student knowledge as continuous with scientific knowledge. These views of the value of students’ understandings are evident in the rhetoric in current science education literature and in documents supporting the NGSS (Campbell et al., 2016; National Research Council, 2012).

Additionally, there is a strong research tradition arguing that students’ community and culturally-based intellectual resources should be used for knowledge-building in classrooms (Warren, Ballenger, Ogonowski, Rosebery, & Hudicourt-Barnes, 2001). For example, “Funds of Knowledge” research argues that schools should connect content goals to the historically accumulated knowledge and skills from students’ communities (i.e., Moll, Amanti, Neff, & Gonzalez, 1992). This framework positions students’ cultural knowledge as a missing component of curricular content, and places great value on home and community-based expertise in the school. Other research, such as “expansive interpretative power” (Rosebery, Warren, & Tucker-Raymond, 2015), emphasizes teachers’ interpretation of students’ ideas during instruction, and the enactment of practices that promote and respond to varied ways of thinking. For example, González-Howard and McNeill (2016) describe teachers’ questioning practices as being pivotal in soliciting students’ experiences as evidence in argumentation. Furthermore, Miller et al. identify “leveraging students’ lived experiences” as central to learning environments that support rigorous explanatory discussion (Miller, Lauffer, & Messina, 2014).

In the vignette, instructional approaches that seek to value students’ ideas as resources are evident in the structure of the activity and the specific design of the lesson. For example, Ms. Adah situates the discussion in the students’ local community so that their understandings and experiences (e.g., swimming and fishing) are relevant and valued. The students begin the unit by making observations together so that everyone has the opportunity to generate ideas. With this structure and design in place to elicit many students’ ideas, Ms. Adah helps the class follow the thinking of various students as they connect their first-hand experiences with the different temperatures in the lakes, biology in the lakes, information from expert sources, and data from their investigations to develop scientific explanations and solutions.

However, even in discussions that are structured to value and encourage student ideas, some knowledge and lived experiences are necessarily foregrounded while others are sidelined by the teacher’s responses. For example, in the vignette, Ms. Adah uses structures that were designed to elicit and build on student ideas based on cultural resources and experiences, however, in other ways she may have restricted the students’ opportunities to perceive the classroom as affording the epistemic agency necessary to offer knowledge. Consider Ms. Adah’s response to Kanye’s idea that the spiny water flea might “not know better” than to remain in a hostile environment. Unlike Aleena’s idea, Ms. Adah did not understand Kanye’s idea, and subsequently did not substantively engage with it. Instead, she invited discussion around the ideas that she anticipated, or were better aligned with canonical scientific ideas (e.g., predation). Despite efforts to surface ideas, her response (or lack thereof) had the consequence of demoting Kanye’s idea, while elevating other students’ ideas and lived experiences, particularly those that are more directly (and obviously) in line with the learning goals identified by the teacher or the curriculum. This brief analysis raises the question: When the teacher has primary responsibility for soliciting students’ cultural and intellectual resources and assigning value to those resources, how can diverse (and potentially divergent) ideas and ways of thinking (such as religious, cultural, and political beliefs) still be assigned equal value in the classroom community?
Moreover, when the selection of particular, often anticipated, experiences, ideas, and ways of thinking occurs repeatedly over time, students are able to use knowledge of the classroom’s historic structures and practices to infer which contributions are likely to be taken up. Thus, those students whose ideas and experiences are less likely to be elevated to the public plane of classroom talk are increasingly unwilling to participate in the knowledge building work in their classroom (Bang, Warren, Rosebery, & Medin, 2012; Brown, 2004). In this way, the process of selecting particular ideas for further discussion might unwittingly promote student self-censorship as students anticipate the teacher’s selections. For example, consider a student Moje et al. (2004) highlight—Tana. Tana used her experiences burning tortillas to connect to ideas about incomplete combustion in her science class. When the teacher told the class that smoke is always white, she whispered to her friend, “no it’s not, it’s black,” but does not make this idea public for the class. This choice suggests that the community was accustomed to using the measure of “alignment to teacher expectation” to assess value. However, if the community relied on connectedness, affordance, or uniqueness for assessing value and credibility of potential resources, Tana might not have muffled her idea. Tana’s example and Kanye’s question lead us to ask: When we say that we value students’ intellectual resources, are we only valuing those that we see as moving us along a pathway toward desired learning outcomes, or are we ready to re-imagine what the knowledge construction looks like based on the ideas that students offer in the classroom (Rosebery et al., 2015)?

These examples highlight that attempting to make connections to students’ lives and position their ideas and experiences as “resources” is not sufficient to promote students’ capacity to take up epistemic agency. We can easily imagine a complacent approach to NGSS enactment, in which teachers set up an initial community-based problem or anchoring phenomenon to elicit students’ ideas, but only build on those ideas that are recognizably aligned to the learning goals specified in the curriculum and in the standards. We must grapple with deeper questions about how to provide opportunities for student ideas, and home and community-based intellectual resources, to be considered as potentially valuable to the science work. To move toward classrooms that enable epistemic agency, we must understand when and how learning communities place epistemic value on cultural and intellectual resources, especially those that may be viewed as divergent from the perspective of canonical science. For example, Bang et al. (2012) have challenged us to think about how native epistemologies—that have historically been seen as divergent from scientific views—can be productive resources for science instruction, as well as how we (e.g., researchers in science education) may need to question what we take as science. In contrast, others have documented how religious and scientific epistemologies can be approached as distinct and discontinuous, and how teachers and students can develop critical stances toward discontinuities (Krakowski, 2013). This work highlights the need to further explore both how all ideas and epistemologies can be positioned as potential resources for building knowledge and how all stakeholders (e.g., students, teachers, and researchers) can take critical stances toward their own assumptions and approaches.

If we seek to promote epistemic agency, we must address questions such as: Does the transplanting of a cultural resources to school-based contexts enable epistemic agency, or does it create new barriers? Does building on some resources more than others send problematic epistemic messages about whose knowledge counts? Can teachers purposefully shift the value placed on the knowledge and experiences of all students? Can unexpected or “divergent” resources that students use to make meaning in science (such as religion, spiritual beliefs, or perhaps a denial of climate change) be positioned as valuable and seen as such, even as the connection to science may be initially unclear to the teacher? To foster critical evaluation of ideas, should all sense making resources that are offered in a classroom be treated with equal potential, and equal skepticism? Last, can classrooms be contexts where students learn to critically examine the process by which knowledge becomes valued and devalued in a community?
3.2 | Epistemic agency opportunity 2: building knowledge

A second opportunity for epistemic agency that is broadly endorsed by the field of science education is engaging students in the construction of scientific knowledge (e.g., National Research Council, 2012; Piaget, 1972). In the NGSS, eight science and engineering practices are central to positioning and enabling students to construct knowledge. The standards shift from requiring students to demonstrate knowledge toward asking them to engage in practices to construct, question, and communicate understandings. For example, rather than merely assessing whether students can list properties of matter, the fifth-grade standard asks students to demonstrate that they can “make observations and measurements to identify materials based on their properties” (Achieve, Inc., 2013, 5-PS1-3). The description then articulates the practice as students “producing data to serve as the basis for evidence for an explanation of a phenomenon.” The implication of the performance expectations, as written, is that students act with epistemic agency as they construct knowledge through engagement in the practices of scientists; that participation in the practices is a route away from students’ typical roles as passive recipients of information.

In the vignette, students engage in science practices in ways that align with the NGSS and that appear to position students with epistemic agency. For example, they construct predictions, design solutions to a problem, and synthesize information from multiple sources, such as empirical investigations and graphs. They take on the roles of scientific community members who hold each other accountable to providing evidence and revise their thinking in light of feedback from peers. Thus, students are participating in activities in which they leverage scientific knowledge and develop shared understandings, rather than memorize and repeat information.

While the field of science education agrees on the importance of science practices as an avenue for knowledge construction, there is substantial variation, both across the research literature and in curricula developed in response to the standards, in how students are introduced to and engage in the practices. We argue that these differences have important implications for whether students would actually perceive themselves as epistemic agents with the capacity to engage in and shape their classroom’s knowledge-building work. Specifically, we wonder how to reconcile the notion of practices as locally constructed to solve shared problems with a goal of having students engage in the practices of disciplinary experts whose activities are located in a very different system of goals, norms, and identities (Hogan & Corey, 2001; Rudolph, 2008). Several authors have argued that students’ opportunities to perceive and act with epistemic agency are limited when they engage in pre-determined practices without perceiving the practices as meaningful in their work (e.g., Berland & Hammer, 2012; Lehrer & Schauble, 2012; Manz, 2015a, 2015b; Metz, 2008; Russ, 2014).

What the vignette leaves invisible is how Ms. Adah introduced and supported engagement in the practices. One approach to supporting scientific practices is to describe the practices in which scientists are understood to engage, model and scaffold those structures, and develop scoring guides to rank students’ alignment to the “correct” enactment of the practices. For example, Ms. Adah may have spent the last several months repeatedly telling her students that they must cite empirical data from their investigations as evidence and grading the fidelity to which students adhered to “correct” structures and forms of evidence. In this scenario, students’ work with evidence would illustrate their capacity to follow the practices of science as mandated by an authority, rather than their work as epistemic agents.

In contrast, Ms. Adah might have positioned the scientific practices as powerful tools for students to take up, interrogate, and adapt for their purposes (Wenger, 1998). In this case, the vignette would illustrate students’ very real, meaningful attempts to draw on specific tools for specific parts of their sensemaking work. As Pickering (1995) describes, students would act with epistemic agency by knowing what tools to draw on for particular purposes or constructing new tools, allowing those tools to do work for them, and then refining tools and understandings. Here, students would not be assumed to
have agency because they were acting out the practices mandated by the teacher; instead, they would be positioned with the agency to shape (and potentially change) their class’s science and engineering practices. This take on the NGSS practices is one that is increasingly put forward in theoretical pieces and close qualitative analyses (e.g., Krist, 2016; Manz, 2015a; Ryu & Sandoval, 2012). However, such learning environments are complex to design and sustain, and as a result, science educators and researchers lack examples and evidence to share with policymakers, curriculum designers, school leaders, and teachers.

In the absence of elaborated theoretical or design principles, it is easy to make assumptions about who should, when they should, and under what conditions they should, have the agency to enact and transform practices that are sensible to them. Thus, a complacent approach to instantiating the NGSS could emphasize the “doing” of science for the purpose of knowledge construction, yet funnel students toward an externally-determined, authority-described version of what scientists do. For instance, it is possible to argue that because elementary students lack particular skills, knowledge, and beliefs, they should be taught these practices directly and encouraged to use the practices in their “correct” form. That is, elementary students might be considered to later be able to enact the practices with agency, but for now, should be taught to engage in the practices with fidelity to professional science. In this model of engaging students in the practices, educators ask themselves when students are “ready” (i.e., have the appropriate foundational knowledge or skills) to act with agency. This approach is easier to communicate and provides a less arduous route for curriculum developers and district leaders to travel; in fact, in our work with districts and reviewing new curricula, we often see this approach to the practices.

However, several scholars argue that a “put off until later” approach to engaging students with agency around science and engineering practices might be problematic. First, this approach elicits echoes of what Matusov et al., (2016) describe as a prevailing approach toward agency in education of using “coercive means to set the learning goals and values for students, with the ethical justification that such coercion is good for the individual because it will lead to the capacity for autonomy later” (p. 424). Second, the literature is replete with examples of young children participating in sophisticated forms of scientific sensemaking (Danish & Enyedy, 2007; Hammer & van Zee, 2006; Metz, 2011). Additionally, many scholars also argue—from both a theoretical and empirical basis—that if students are only positioned with and allowed to take up agency later in schooling, after they have some acquired foundational knowledge and skills—then students may be conditioned not to recognize and take up these opportunities when finally granted (e.g., Lising & Elby, 2005; Russ, Coffey, Hammer, & Hutchison, 2009). This work highlights concerns with assuming that any group of students is not yet ready to exercise agency in relation to the practices.

In short, if we do not explicitly interrogate and communicate about the importance of students shaping the science and engineering practices and of positioning the practices as purposeful tools for students in their current activity, then the NGSS practices will likely become yet another authority-mandated set of rules and standards that are placed on students, rather than an opportunity for students to perceive and enact epistemic agency through their knowledge building practices. Rather than considering student readiness, a more powerful approach might therefore be to ask, given particular ages and epistemological orientations of students, “under what conditions will students see a need for approximation of a scientific practice, and under what conditions can they further participate in shaping that practice in the context of its use?”

To support more authentic opportunities for epistemic agency, classroom learning environments could emphasize the local nature of practices and provide opportunities for students to co-construct, adapt, and evaluate knowledge building practices. Yet, many questions remain around how to design and orchestrate learning environments where students can shape classroom epistemic practices. How
can we justify the choice to specify and introduce structural aspects of a practice as norms that empower students, rather than as exterior expectations that remove their agency (Delpit, 1988; Nasir, Rosebery, Warren, & Lee, 2006)? How do we navigate the tension between a need to scaffold practices without the scaffolding manifesting as a tacit transmission model for these structures? What does it mean to assess students’ participation in science practices, and how can we do so in ways that are fair and respectful? How do the environments that we create support and limit the practices that students engage in?

3.3 | Epistemic agency opportunity 3: building a knowledge product that is useful to students

A third opportunity for epistemic agency involves prioritizing the development of knowledge that is useful and meaningful to students’ current and future sensemaking. That is, students should be given opportunities to “figure out” answers to their questions rather than “learning about” canonical facts (Schwarz, Passmore, & Reiser, 2017). This requires that students will be identifying sub-questions they need to answer and possibly phenomena to explore to meet their larger goals (Berland et al., 2016), rather than learning canonical ideas that match their teacher’s expectations. Our field’s commitment to students building knowledge that is useful for their learning can, in some sense, be traced back to Dewey’s (1916) vision of education. In that vision, the student is trying to understand an authentic problem in nature that is part of their experience, rather than trying to learn a fact or idea because it is part of the body of canonical knowledge.

Our field has increasingly emphasized the importance of students building knowledge that they find useful. We see this commitment prevalently in the curricular approaches to situate student work in meaningful contexts (i.e., anchoring events, Cognition and Technology Group, 1990; project-based science, Blumenfeld & Krajcik, 2006; engineering or design challenges, Kolodner et al., 2003; and coherent storylines around problematized ideas, Fortus, Sutherland Adams, Krajcik, & Reiser, 2015). It is hoped that contextualization supports a sense of agency around the content learned because it ensures that the students perceive the content they are learning as being useful to themselves via three avenues:

1. The content is contextualized through an authentic problem or phenomenon, such that students are learning content to solve that problem—the content serves and obvious and immediate purpose (Edelson, 2001; Schwarz et al., 2017);

2. The problems or challenges students explore in these meaningful contexts frequently do not have an immediate answer. Instead students will need to pursue multiple investigations and answer numerous smaller questions in the service of fulfilling the larger goal. This creates opportunities for students to ask questions such that they are able to follow learning trajectories that align with their sensemaking rather than the goals of others; and

3. Science units that take this approach are typically based on learning progressions that describe expected patterns of changes in student ideas in a particular instructional context. In this way, the unit can seem to flow from students’ own questions such that they experience their ideas and questions as driving the explorations (i.e., they will ideally experience the class’s investigations as building knowledge to address their own questions and ideas).

In the vignette, Ms. Adah has students develop meaningful knowledge although a project-based-science approach in which the unit-long project centers on a driving question. The overarching learning goal of the unit is for students to make a prediction based on scientific ideas and engineer a solution to protect the lake. In this case, there is no single correct answer toward which students are driven.
Instead, students, guided by Ms. Adah, pursue questions and avenues for exploration that emerge during the unit as meaningful and useful for their own problem solving. For example, consider Max’s question and Ms. Adah’s response at the end of the vignette. In this case, Max’s reasoning leads him to ask: “Is light just the same as heat? And doesn’t it matter how far down it goes...?” This appears to be a direction that Ms. Adah does not expect, but it grew naturally out of Max’s own sensemaking work, and is consistent with the ideas and evidence that the class has been discussing. Thus, when Ms. Adah responds by suggesting Max and his peers reflect on his question and to consider ways to explore it further, she positions Max as able to construct knowledge that is useful to his own sensemaking and problem solving. That is, she is asking him how to answer questions he had raised in his own efforts to fulfill the project goals.

Despite our attempts to have students construct knowledge that is meaningful, as a field, we have yet to explicitly address the tension between positioning students to construct meaningful knowledge and having them develop correct canonical knowledge (e.g., Deboer, 2002; Hammer, 1997). However, there may be times when the knowledge that is useful for students as they pursue rich understandings of the physical world is incorrect. For example, physicists often model physical systems as frictionless or distributed bodies as point-masses. Although those models are simplified—so much so as to be incorrect—they are nonetheless useful for understanding the dynamics of force and motion. Or, as Russ et al. (2009) describe, there may be times when students may have an incomplete yet functional idea, and the teacher correcting it actually moves students away from meaningful understanding and toward rote memorization of the canon. We argue that our field has not resolved how classrooms can provide this opportunity for epistemic agency when traditional emphases on students learning accurate facts and theories remain (Rudolph, 2014).

The tension between the expectation that students will construct useful knowledge and that their knowledge products be canonically accurate is evident both in the literature (e.g., Bouillion & Gomez, 2001; Furtak, 2006; Russ et al., 2009) and in the very structure of NGSS. For example, consider NGSS performance expectation 3-LS3-2 (Achieve, Inc., 2013):

*Use evidence to construct an explanation for how the variations in characteristics among individuals of the same species may provide advantages in surviving, finding mates, and reproducing.*

When fulfilling this performance expectation, it is possible to require students to construct a coherent mechanistic explanation that aligns with correct canonical understandings of species variation. However, it is also possible to fulfill this expectation with an evidence-based explanation that is not canonically correct; for example, an explanation that incorrectly identifies benefits of particular variations would still fulfill the expectation. We, as a field, have not clarified which of these interpretations should guide our instruction.

The vignette provides a clear moment in which this tension unfolds. At one point, Aleena asks the class a question.

*Why would the spiny water flea like cold water best? It clones itself fast, every three weeks in warm water. It doesn’t make sense, it should love warm water.*

From the perspective of the canonical answer, Aleena is wrong. The water flea does not have preferences about where it lives. Moreover, the understanding Aleena is expressing is often considered problematic—some educators worry that anthropomorphic understandings are less valuable than mechanistic accounts (Russ, Hammer, Scherr, & Mikeska, 2008). However, other researchers have noticed that these sorts of informal metaphors for discussing animals’ structures and behaviors do not necessarily hinder more canonical understandings (Tamir & Zohar, 1991; Zohar & Ginossar, 1998) and are
often apparent in the way that biologists talk (Madrell, 1998). In the vignette, Ms. Adah responds to Aleena by correcting her use of this reasoning by saying, “First of all, we can’t really use the words prefers and likes, I think. Because we are talking about adaptation, not preferences.” In this moment, Ms. Adah may have shifted the goal for Aleena—away from making sense of the spiny water flea and toward using canonically correct ways of reasoning about adaptation. In doing so, she may have undermined Aleena’s epistemic agency to pursue knowledge that is meaningful for her.

We worry that if science educators enact a complacent instantiation of NGSS—one that solely expects students’ knowledge products to be canonically accurate—classroom activities will lend themselves to a display of pseudoagency where students will be treated as agentive in constructing useful knowledge, only to the extent that they construct expected/canonical knowledge products. Thus, while contextualizing knowledge development in complex problems does a substantial amount of work to organize instruction around common student-centered trajectories (rather than disciplinary-centered trajectories), the end point of those trajectories requires additional unpacking if we are to enable students’ epistemic agency. Therefore, we suggest that the field still has important questions to address in relation to how we position and bring into contact our values for canonical understandings and for students engaging in meaningful sensemaking. At what grainsize and how often do students need to feel that they are constructing knowledge that is meaningful to them (i.e., is it possible to enact epistemic agency at the unit level but not the lesson level?)? Is the vision of three strands, as embodied in the NGSS, compatible with this type of epistemic agency in which students construct knowledge for their own purposes?

3.4 Epistemic agency opportunity 4: changing structures that constrain and support action

The fourth opportunity for epistemic agency in classrooms involves the positioning of students as change agents in the local and global structures that constrain and support tangible action (Miller, Januszyk, & Lee, 2015). For example, researchers have argued that engaging in activities such as the informal planning and planting of an urban garden (Fusco, 2001), and using science ideas about nutrition and health to transform food systems (Barton et al., 2005) can enable students to use science to disrupt power structures. This opportunity for epistemic agency reflects individuals’ capacity to shift their context and take a critical stance toward established ideas and practices, using historical and future-oriented lenses (Barton & Tan, 2010; Engeström & Sannino, 2010). Here, we consider epistemic agency in terms of a students’ capacity to produce an effect on the world (Kaptelinin & Nardi, 2006).

The field of science education has attempted to promote epistemic agency in students’ capacity to change local structures by situating science learning within “real-life contexts” (e.g., Basu & Barton, 2007; Buxton, 2010). The purpose of situating science in “real life” is to engage students in knowledge building that leads to social action (particularly changes in inequitable structures) in their immediate communities (Ladson-Billings, 1995, Barton & Tan, 2010). Such literature proposes that the effect students can have in addressing these problems and questions can go beyond learning about the world within the four walls of the classroom, toward acting in and affecting the world (Eisenhart, Finkel, & Marion, 1996).

In the vignette, Ms. Adah introduces the unit with a problem she believes is concerning the community—that local lakes need protection from the spiny water flea. The students appear to be invested in the local problem, seeking to understand the invading species, the ecosystem of the lakes, and considering how to take action to protect the lakes. Students also appear to take ownership of their ideas, and Ms. Adah provides opportunities for them to experience their ideas as having the potential to influence their local communities.
However, the history and culture of the surrounding community can create tensions for students taking up positions as agentive in relation to larger structures. If students are meant to use their science knowledge to problematize injustices through social action (thereby being epistemically agentive), the larger (invisible) community context needs to be revealed, examined, and disrupted. For example, a socio-critical stance toward education (Ladson-Billings, 1995) questions whether anyone can take an objective stance—one that does not acknowledge or account for differences in power within the community—toward community issues. Students’ (and families’) experiences in a community are not monolithic, and they bring various and contrasting perspectives of membership to discussions related to the community. In these contexts, it is often the case that the experiences of the “problem” by the privileged members of the community are tacitly given priority.

In the vignette, the spiny water flea is transported by boats that only a few members of the community may use, and some students’ families rely on the fish in the lakes for food. Still other students may be undocumented and thus be uncertain if they should have a say in creating solutions for publicly owned property. Ms. Adah must negotiate whether and how to surface students’ perceptions of the problem, each of which are potentially dramatically different—and even contradictory—depending on how their sub-communities interface with problem. In the vignette, Ms. Adah tacitly chooses to circumvent this negotiation by keeping the discussion “objective.” She guides discussion toward weighing facts and using evidence as the primary valued form of participation. The students follow her lead and refrain from sharing personal stories and experiences within their sub-communities, and also hide emotions that might accompany reasoning about place.

The vignette demonstrates how having students discuss community problems does not automatically create opportunities for students to see classroom science as relevant to changing structures in their community, and to feel that they can change these structures. A complacent approach to the NGSS might structure learning environments based on “problems relevant to students’ lives,” yet can still ignore multiple, potentially contradictory community needs might come into tension in negotiating epistemic agency. To fully realize the potential of community-based science to afford epistemic agency, some thorny questions will need to be explored, including: How might science learning environments be designed to surface and allow students to grapple with tensions around whose experiences and perspectives count in community-situated problems? How do we (and should we) support students in developing ideas for social change when there are historical and institutional factors that inform the power structures that exist within communities? How can we, as science educators, evaluate when and how we need to make the socio-political aspects of a science phenomenon apparent?

4 | DISCUSSION

The notion that students should take an active role in knowledge construction is central to the vision of NGSS and to the work of many researchers seeking to support NGSS implementation. In this article, we have used the construct of epistemic agency to analyze how NGSS-aligned instruction might allow students to be positioned and to take up roles as powerful science knowers and doers. We described how science educators conceptualize four opportunities that could position students with epistemic agency: eliciting students’ ideas and experiences; engaging them in science practices for building knowledge; enabling them build a knowledge product that is useful to them; and positioning science as a way to allow students to make changes in larger societal structures (i.e., to see science as meaningful for their lives and their communities).

However, when we looked more closely at how each of these opportunities is being taken up, we identified tensions and contradictions that call into question whether we are substantially shifting how students are positioned and how they experience science instruction. That is, we can elicit students’
ideas while positioning those ideas as resources to be used within a pre-determined framework, rather than as resources that help students connect their lived experience with scientific pursuits. We can ask students to engage in the practices of scientists without treating practices as locally-constructed activities that students must shape and find meaningful. We can contextualize science content in ways that make it useful, but not consider actions to take when students do not reach the canonical answer, therefore possibly setting up a false sense of control around students’ engaging in sensemaking. Finally, we can situate science in real-life contexts without taking seriously how these contexts problematize the meanings and uses of science for students. In relation to each of these sets of contradictions, we identified questions that we believe that the field must address to move toward more nuanced and generative understandings of opportunities for epistemic agency.

We argue that unless we address these contradictions and questions, we are likely to implement NGSS in a way that is complacent with historic student roles, thereby preventing students from perceiving and acting with epistemic agency. In the remainder of this article, we first describe why this work is important, and then confront the difficulties science educators and teachers face in positioning students with epistemic agency. We conclude with a call to action and a caution about presenting an unproblematic message about NGSS to colleagues in schools and districts.

### 4.1 Why this work is important

Given this theoretical and practical complexity, one might wonder: why bother? Why must we be concerned with whether students are positioned with, perceive themselves as having, and act with, epistemic agency in their science classrooms? One answer to this question centers on the nature of learning; ample research on constructivism (and its descendants) shows that more meaningful learning occurs when students construct knowledge. Another answer centers on the meaning of science; science, in part, involves constructing new knowledge. Here, we highlight another, even more important answer—one that illuminates the role of epistemic agency in developing learning environments that are more epistemically just.

When we explicitly support a particular form of knowledge and sensemaking as one that we want students to take up, we send messages about whose ideas count and for what purposes (Barton et al., 2012; Gresalfi et al., 2009; Matusov et al., 2016). In this way, we not only shape what students do, but we influence their perceptions of themselves and their peers as knowers and shapers of knowledge, as well as their ideas about who can and should participate in science (Russ, 2018). Students’ perceptions of themselves as having and enacting epistemic agency is important because when a person’s credibility as a knower or reasoner is inappropriately and unwarrantedly undermined (i.e., preventing the possibility that they might perceive themselves as having epistemic agency), an act of epistemic injustice—and over time, epistemic oppression—occurs (Dotson, 2014; Fricker, 2007). Both Fricker (2007) and Dotson (2014), philosophers studying epistemic agency, highlight that the results of acts of repeated epistemic injustice are profound both for the individuals who experience the injustice and for the epistemic community (or communities) of which they are a part. For the individual,

*The implication for persistent [epistemic] injustice is that the subject’s intellectual performance may be inhibited long-term, their confidence undermined, and development thwarted* (Fricker, 2007, p. 58).

Note two features of Fricker’s argument. First, she asserts that epistemic injustice can result in the loss of intellectual courage such that the student’s developing the ability take a stance and argue for their point of view is hindered. Second, students may lose confidence in any existing knowledge and/or justifications for that knowledge as a result of epistemic injustice. That is, experiencing persistent
epistemic injustice may cause students to wonder: “If my thinking about this question is not worth attending to, is any of my other thinking worth attending to?” These effects of epistemic injustice can result in epistemic oppression, such that students no longer perceive of themselves as capable knowers and reasoners in science (c.f., Brown, 2011).

Moreover, the effects of epistemic injustice are not limited to the individuals who experience it. Rather, communities in which epistemic injustice exists become ineffective spaces for knowledge building. Communities that regularly silence the voices of some knowers develop epistemological resistance in that these communities do not allow the knowledge and ideas of those perceived as “non-knowers” to shift the collective perspectives and understandings. In this way, the ideas the community constructs are weakened, and the community suffers accordingly (Dotson, 2014).

The existence of epistemic injustice—and its implications for the knowledge building of individuals and classroom communities—make questions about how to create opportunities for epistemic agency particularly acute. Unless we, as a field, begin to tackle the complexities inherent to epistemic agency, NGSS may be enacted in classrooms in ways that undermine our very purposes in articulating the new standards.

4.2 | Why this work is difficult

The contradictions and complications articulated in this article leave us with the need to embrace a stance that any desire to create or re-allocate opportunities for agency is inevitably linked to structures that afford and constrain that agency (Giddens, 1979; Varelas, Settlage, & Mensah, 2015). Thus, neither the NGSS, nor good intentions to change participation structures within classrooms, will radically shift science and school communities. Four levels of structure within which the NGSS enactment are implicated in the possibility of a complacent adoption of NGSS; these will complicate efforts to realize a vision of students being constructors of knowledge and “doers” of science in the NGSS-aligned science classrooms.

First, there is the inherent power structure of the classroom, which places an emphasis on the teacher as the sole content and pedagogical authority. Such teaching, which Papert (1993) called “instructionism,” features teaching actions to control what students think and how students participate in science (Sawyer, 2006). We know that the historic gulfs of epistemic power are deeply entrenched in classroom systems (e.g., Apple, 2013; Ladson-Billings, 1995). We also know that when teachers are introduced to reform-oriented strategies that seek to shift power to students, the result is often the interpretation that shifting power to students means that the teacher relinquishes all control, an untenable and ultimately useless position (Chazan & Ball, 1999; Furtak, 2006). We saw related complications emerge in our discussion of opportunities for epistemic agency when student ideas and resources do not align with the teacher’s curricular goals.

We argue that there are important differences between small tweaks and quick fixes to teaching (e.g., asking leading questions and enacting disconnected instructional strategies) and substantive change in promoting students as epistemic agents. We do not blame teachers for pedagogies that artificially create gulfs of epistemic power with students; teachers often face pressure to adhere to various policies aimed at maintaining teaching that embraces strict and typical power dynamics between teachers and students. Our concern is that teachers now shoulder responsibility for enacting seemingly competing aims—while teachers are typically positioned as the pedagogical and content authority, dismantling epistemic injustice requires teachers to relinquish some authority to students, including epistemic responsibilities. However, a lingering question remains—how can teachers avoid merely layering their version of epistemic norms and practices onto students’ learning opportunities, thus maintaining epistemic authority and positioning students as pseudo-agents? This is a question that the
field must continue to surface and address in our research and our work with teachers and school and district leaders.

A second structural consideration is the fact that students do not enter science classrooms with equal epistemic positions in relation to each other. That is, some students enter classrooms as knowers and others do not because of entrenched social and political power structures (e.g., Basile & Lopez, 2015; Carlone & Johnson, 2012; McGee & Martin, 2011; Nasir et al., 2006). Moreover, minoritized students are consistently treated as although their knowledge and ways of acting are “less,” or irrelevant, insofar as they appear and are taken as discontinuous with school norms and dominant paradigms of science (e.g., Rosebery et al., 2015; Seiler, 2013). As a result, we cannot say we want to provide “all” student opportunities for epistemic agency and pat ourselves on the back for a job well done (Brown, 2011; Rodriguez, 1997); the differential positions of students will remain if the complacent approaches to epistemic agency we documented here are enacted. In that case, the very students whose experiences of science we most want to affect (i.e., those whose concerns and ways of engaging with science least resemble the knowledge and practices reified in the NGSS), will be systematically left out of our reform efforts, yet again.

Consistent with colleagues who have conducted extensive research in this area, we believe that we must move beyond the rhetoric of blanket statements such as “all students will learn science,” and toward actions that support the individuals and communities that exist in local science learning settings (Carlone, Haun-Frank, & Webb, 2011; Nasir et al., 2006; Rodriguez, 1997). Treating the classroom as a learning community in which students’ ideas have value, and in which each person supports each other’s learning and participation, is fundamentally different than classrooms that (even unintentionally) re-inscribe systems of competition and individual success. Such communities are difficult to create, examine, and describe, yet we need a more complete picture of classrooms in which power structures are shifted over time and these descriptions must be seen as essential to the implementation of NGSS, rather positioned as a separate endeavor (Brown, 2017; Rodriguez, 2015).

Third, NGSS implementation and the translation of our values for epistemic agency into practice are situated in larger historic systems and structures of schooling. Consider the translation of the ideas in the Framework for K-12 Science Education into the standards document that is largely driving implementation. To provide a focus for assessment and curriculum planning, the practices and target content understandings were paired into a description of grade-level appropriate participation in practice with a declarative statement of knowledge. The emphasis necessarily skews toward a simple and easily articulated set of practices and target content understandings, rather than the complexities of local practice that we have argued are central to deep opportunities for epistemic agency.

We recognize and understand that simplifying the meaning, practices, and purpose of the NGSS is an enticing path given the complexity of schooling on local, state, and national levels. However, this path of simplification risks missing an opportunity for fundamental shifts in teaching and learning. This problem is exacerbated by the fact that these standards are interpreted by curriculum developers, assessment designers, and district leaders with limited time and capacity to implement deep changes. These moves are part of a well-documented process that has allowed schools to perpetuate existing structures via an effective “immune response” (Papert, 1997, p. 419) that “resists the reform in a particular way—by appropriating or assimilating it to its own structures” (ibid, p. 420). As a field, we must struggle with how we can work within these structures to realize the vision that drove the standards.

Fourth, the structure of our society’s, and indeed our field’s, definition of “science” is at play in any deep consideration of epistemic agency. Our fixed understandings of science interact with all of systems described above: teachers are positioned as the keepers of canonical science, students are taught right ways of acting and thinking, and our typically westernized notion of science inherently privileges some knowledge and knowers over others. Unless we recognize, articulate, and unpack what
we take as science, we cannot make progress is developing opportunities for all students to learn science with epistemic agency (Bang et al., 2012). This structure is perhaps the most difficult for members of our field to call into question, as we have a commitment to, and a stake in, views of science as a discipline.

These structures are not new—nor are they unknown to many of our colleagues in education. In fact, there are many in our sub-field of science education and the field of education writ large that have devoted their careers to the study of these structures—how they are established globally and manifested locally, how they change and develop over time, and how they afford and constrain the work done within them (e.g., Gutiérrez, 2008; Ladson-Billings & Tate, 1995; as well as the citations above). There are many strong and significant voices who have repeatedly drawn our attention to how these structures are embedded in—and thus complicate—how students and teachers are positioned in the classroom.

What we can learn from these researchers is that placing focus on local interactions between teachers and students will ultimately miss the proverbial forest for the trees. Inequity in whose knowledge counts in classrooms, while played out at the interactional level, is embedded in larger, historical systems that locate power in particular individuals, ideas, and ways of knowing. To make progress then in understanding the implications of epistemic agency, we will need to understand the ways in which systemic oppression is inscribed and re-inscribed in classroom interactions around knowledge (Bartlett, 2005). We need the expertise of multicultural scholars, curriculum theorists, critical race scholars, practicing teachers, and many others. The onus is on us to enter their discourses—not they into ours—if we hope to articulate opportunities (and challenges) of the NGSS’s promise of equitable science instruction in which all students construct knowledge through the scientific practices. If we do not purposefully engage in these discourses, then ideas such as epistemic injustice—that complicate the NGSS—may be relegated to the fringe of our field.

5 | CONCLUSION

We end the article by acknowledging that the NGSS is both a knowledge product that incorporates understandings and commitments developed over decades of science education research, and a framework for new knowledge generation. As such, the NGSS wield enormous power: they will shape how we frame our research papers and our funding proposals, and how we gain entry into partnerships with practitioners. With this power comes the impetus to claim and promote coherence—to say that we have developed a clear picture of implementation and a common set of principles and practices. We intend our work here to push against this impetus by collecting and exposing questions and concerns other scholars have highlighted for decades and giving them deliberate reflection by juxtaposing them against the NGSS. We must acknowledge these questions and contradictions, recognize them as tensions, and work collectively—both inside and outside the field—to grapple with them.

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