Viewing Science as Practice: Implications for the Language Development and Inclusion of English Leaners

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Abstract: The science education community is moving towards a view of science-as-practice. In this theoretical analysis, we propose that the shift requires a corresponding reconsideration of how language is viewed in the science classroom. We argue that common conceptualizations of language in the science education literature are insufficient and propose an alternative, van Lier's *ecological* model of language. Using the practice of argumentation as an example, we show how an ecological approach would change how language is supported in the science classroom. Such a change has the potential to disrupt traditional narratives of competence in science, particularly for students from non-dominant cultural and linguistic backgrounds.

Introduction

The landscape of science learning in the United States is rapidly changing. Policy documents such as the Framework for K-12 Science Education forward a view of science that stands in sharp contrast with traditional notions of science learning (National Research Council, 2012). While previous frameworks were based on the concepts that students should *know*, the NGSS are based on things students should *do* – called the practices of science (Osborne, 2014). By engaging in scientific practices, students learn to be critical producers of knowledge rather than passive consumers. The notion of science-as-practice derives from more than fifty years of work in Science Studies, an interdisciplinary field that employs philosophical, anthropological, and sociological perspectives (e.g., Latour & Woolgar, 1986; Longino, 2002). This work frames science as a normative set of values and practices that have been negotiated by members of the community.

At the same time, more attention is being paid to how students from culturally and linguistically diverse groups engage with science. Multicultural and multilingual students, many of whom are labeled as "English Learners" (ELs), represent a growing proportion of students (Sugarman & Geary, 2018). Although science is commonly viewed as objective and universal, its practices represent the middle-class, European cultures in which they developed (Kimmerer, 2013). There is a "foundational contradiction" in the efforts to engage students in the practices of scientists; educators seem to mean that we want students to "mimic" the practices that we have selected in ways that are recognizable to us (Miller, Manz, Russ, Stroupe, & Berland, 2018, p. 1053). Normative views of scientific practices may not align with the ways that students from non-dominant backgrounds engage their intellectual resources to make sense of science ideas together.

In this paper, we explore how this contradiction plays out in terms of language. Over the last three decades, learning the language of science has been proposed to be a major part of learning science itself (Lemke, 1990; Wellington & Osborne, 2001). Engaging in science practices offer a meaningful opportunity for language development for *all* students, including ELs (Lee, Quinn, & Valdes, 2013). Students use language to communicate their ideas and experiences to each other and negotiate shared understandings. Yet, our expectations of what we think scientific practices should sound like – and the corresponding language supports that we offer – may inadvertently undermine student engagement (e.g., Rodriguez-Mojica, 2018).

In this theoretical analysis, we propose that viewing science-as-practice requires a shift in our conceptualizations of language. The literature on scientific practices emphasizes the situated nature of their development. Yet, much of the science education literature implicitly views language as fixed and universal. We argue that adopting the view of science-as-practice requires a conceptualization of language as dynamic and situated, characteristics that are represented in the *ecological* approach to language proposed by van Lier (2006). From this view, learning environments should support interactions between learners and collaborative meaning making rather than imposing predetermined language forms on students. We discuss how this approach might be implemented in the classroom, using the practice of scientific argumentation as an example. Finally, we draw broader implications for supporting language development in the context of science and suggest how this approach has the potential to reorganize traditional notions of competence in the science classroom.

Theoretical orientation

Sociocultural theories of learning are often used to guide work on engaging students in scientific practices. The sociocultural tradition situates practices in the joint activity of members of a community (Lave and Wenger, 1991). To solve problems and reach desired outcomes, community members generate shared repertoires of practice, such as talk, non-verbal signs, and other actions. These practices develop in accordance with the roles and norms present within the group. Practices are therefore historically and culturally situated. Learning is viewed as changes in participatory practice as an individual engages with others through social interaction. As individuals engage in practices, they develop their own knowledge and simultaneously transform the practices of the community.

Science-as-practice

There has been a general trend away from seeing science as a strictly empirical process in which conclusions are unproblematically deduced from observations. Pera (1994) characterized the traditional notion of science as a play with two actors: the scientists, who propose ideas; and nature, who agrees or dissents. In contrast, Pera argued that a more apt portrayal of science involves three actors: the scientist, who proposes ideas; nature, who speaks; and the scientific community, who determines the interpretation of nature's voice.

The scientific community interprets nature's voice through rhetorical processes such as conjecture and argument. In a widely cited ethnography of a science laboratory, Latour and Woolgar (1986) describe how scientists engage in social interactions to evaluate and critique tentative claims forwarded by their peers. As a knowledge claim stands up to scrutiny by members of the community, linguistic markers of uncertainty are removed from the claim and it becomes accepted as a "fact of nature" (p. 80). Thus, the scientific practice of argumentation, the process through which knowledge claims are debated and settled upon, is central to the establishment of reliable scientific knowledge (Longino, 2002). Although there is some consistency in the rhetorical forms associated with this process, there is also great variation; modes of communication differ based on the scientific subdiscipline (Knorr-Cetina, 2009) and the audience of the work (Latour & Woolgar, 1986)

Genres of scientific communication are therefore social constructs that regularize communication, interaction, and relationships (Bazerman, 1988). In other words, the formal features that are common in a corpus of science texts are linguistic or symbolic solutions to issues that arose in social interaction. Bazerman argued that "static formal features should not hide the social meaning and dynamics of a genre, no more than the active reality of a performed Beethoven quartet should be obscured by the sheet music" (p. 62). Thus, scientific practices, and their associated linguistic forms, arise through processes of interaction; they hold value because they provided meaningful ways to resolve difference between individuals.

Theories of language

Although the science education community has largely embraced the view of science-as-practice, we argue that common conceptualizations of language in the field are insufficient to realize this view. Rather than framing language as a collection of interactional resources, it is often treated as a defined set of universalized features that are disconnected from their use in social settings.

Many science education researchers draw from Systemic Functional Linguistics (e.g., Schleppegrell, 2004), which emphasizes how grammatical choices are used to make meaning in social contexts. For example, Fang (2005) draws from this perspective to identify common features of science texts. Examples include nominalizations (forming nouns from verbs, e.g., conserve → *conservation*), technical vocabulary (e.g., endothermic, invertebrate), and the invocation of an "authoritative" and "assertive" tone. Yet, this work gives little attention given to interactional purpose that these features serve. Furthermore, science learners are framed as "naïve readers" who will struggle to understand these features unless they are explicitly taught. Fang warns against using informal registers alongside formal ones, arguing that that "grossly mixed registers provide a poor model for scientific discourse" (p. 343). Formal linguistic features are taken for granted as desirable; the whether or not these features are meaningful to students as they negotiate scientific ideas is not considered.

We argue that the *ecological* model of language proposed by van Lier (2006) is more consistent with the idea of science-as-practice. This model focuses on how linguistic and semiotic resources present within the community are mobilized in interaction. Van Lier suggests that language is a mediator that always serves a local purpose. Rather than presuppose a purpose for interaction or analyze the correctness and appropriateness of particular linguistic forms, it is the negotiation of purpose *in situ*, within a particular community, that should be analyzed (van Lier, 2006). In particular, van Lier describes language as a system to establish relationships between physical and social entities in a given environment:

> "Language is a process of meaning making…Not only is language a constantly constructed and reconstructed process, it is also inherently a dialogical process…The semiotic process... turns every sign into a dialogic sign...sources of contextual requirements that need to be in place for the assignment of interpretations include: a) shared physical surroundings; b) shared background knowledge; and c) the shared situated definition." (p. 130)

In van Lier's view, the circumstances of a particular interaction offer affordances for making meaning. Participants must consider the material circumstances, their discourse partners, the linguistic resources available in the community, and the purpose of language in a particular interaction. It follows that the language supports must also be relational and available for all participants to adapt in the context of a particular use. If language is viewed as contextual, communicative partners should be supported with flexible tools and semiotic mediators rather than prescribed linguistic features.

The case of classroom argumentation

Argumentation has been the focus of a great deal of research in the science education community (Henderson, McNeill, González-Howard, Close, & Evans, 2017). Although argumentation has been proposed to have significant educational value, it is rare in classrooms (Osborne, 2010). Science lessons continue to be dominated by teacher transmission of information, and the culture of schooling emphasizes being "correct" over exploring uncertain ideas.

Many science education scholars who study argumentation draw from sociocultural theory, though they do so in different ways. Some studies draw from normative conceptions of argument, such as Toulmin's Argument pattern (e.g. Erduran, Simon, & Osborne, 2004). Although these studies situate learning in social interactions, they view argumentation as a universal structure that develops similarly across contexts. Correspondingly, the language of argument is often supported in prescriptive ways. For example, sentence starters (e.g. I claim ___because ___) and scaffolds that use the claim-evidence-reasoning format are common supports for argumentation and constructing explanations (McNeill, Lizotte, Krajcik, & Marx, 2006).

Other studies recognize the role of context in the development of argumentation practices. For example, one study illustrated how the practice of argumentation developed differently across settings (Berland & Reiser, 2011). One classroom constructed argumentation as a way of engaging in collaborative sensemaking, whereas the other focused more on the persuasive aspects of argument. When students viewed the goal of argument as persuasion, they were more likely to hold tightly to their individual views, even in the face of contradictory evidence. In contrast, when students positioned the goal of argument as sensemaking, they were more likely to revise their views in light of new evidence.

What are the implications for language? If language is the means through which scientific practices are developed, it follows that language will evolve as it is used to make meaning. Taking the ecological approach, language goals would be relational and reflexive. For example, students might select from available resources to make sense of erosion – a model, gestures, a water table, or any other means of communicating. If students can communicate their ideas clearly, understand other ideas that are presented, and compare and evaluate the various ideas, they have realized the goals of the lesson – regardless of the linguistic forms they employ.

From this view, prescribing and scaffolding language may not help to realize goals; indirect forms of language support might be more effective. One form of support is to design learning experiences that incorporate uncertainty and complexity, which requires students to use language to resolve differences in their observations and interpretations (Manz, 2015). As difference arises, the teacher can support students in their attempts to understand one another by encouraging them to draw from relevant resources in the environment and by introducing new linguistic resources as they become useful to the interlocutors. This approach stands in opposition to most views of supporting language and language learners, which often seek to prescribe particular linguistic forms and to break knowledge – and language – into small, sequential parts. Another way to support language would be to position students as each other's audience and hold them accountable to one another (Engle & Conant, 2002). In this way, students will be responsible for determining when ideas have been expressed in ways that they find satisfying. Finally, students might be grouped in ways to maximize the linguistic resources available for meaning making. Depending on their interlocutors, students could choose whether to use colloquial language, normative scientific language, other named languages such as Spanish (see Garcia & Wei, 2014) or non-verbal resources such as gestures, diagrams, or physical objects.

If what counts as useful language is negotiated between interlocutors, then notions of who is competent can also shift. In the ecological approach, language is a creative resource that students may use to co-create social meaning. The individual who makes their point most clearly and convincingly will be positioned as competent, whether or not they use standardized grammar, normative features, or a formal register. If effective communication is the measure of competency, a wider range of linguistic resources will be recognized. As a consequence, the power structures that are implicitly embedded in Eurocentric science may be challenged.

Conclusion

The view of science-as-practice has helped the field of science education to reorganize the activity of classrooms. Rather than framing science learning goals solely in terms of prescribed content, we design for what we want students to do (practices) and let the content be constructed as a consequence. Likewise, we need to make corresponding progress in supporting language. The utility of different language forms should arise from the interaction and be evaluated by the interlocutors rather than be prescribed by an authority. In order to translate language theory into classroom practice, more research is needed to learn how to better support students in co-constructing language for particular purposes. While we are optimistic about the potential of the NGSS, we argue for a deeper consideration of language. We believe that doing so will disrupt traditional narratives of competence in science.

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