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FORUM

A view of the tip of the iceberg: revisiting conceptual continuities and their implications for science learning

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Abstract We respond to Hwang and Kim and Yeo's critiques of the conceptual continuity framework in science education. First, we address the criticism that their analysis fails to recognize the situated perspective of learning by denying the dichotomy of the formal and informal knowledge as a starting point in the learning process. Second, we address the critique that students' descriptions fail to meet the "gold standard" of science education—alignment with an authoritative source and generalizability—by highlighting some student-expert congruence that could serve as the foundation for future learning. Third, we address the critique that a conceptual continuity framework could lead to less rigorous science education goals by arguing that the ultimate goals do not change, but rather that if the pathways that lead to the goals' achievement could recognize existing lexical continuities' science teaching may become more efficient. In sum, we argue that a conceptual continuities framework provides an asset, not deficit lexical perspective from which science teacher educators and science educators can begin to address and build complete science understandings.

Keywords Everyday language · Scientific language · School science

Our reflection on the collective critiques found in Yeo's *Finding the science in students' talk* and Hwang and Kim's *Heterogeneous performances of conceptual dis/continuity: a dialectic reading of Brown and Kloser's article* provided ample fodder to further explore the relationship between students' linguistic resources and science understanding. We would first like to commend the previously mentioned authors for providing thoughtful and challenging critiques. Yeo's detailed discourse analysis of our data using the same semantic analysis of thematic patterns found in Lemke's (1990) seminal work on science talk provides insight for expanding the potential scope of our theoretical framework and analysis. Hwang and Kim's use of a dialectal approach to explore the issue of conceptual

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continuity was also fruitful in its attempt to explore student discourse in a broader analytical framework. Overall, the collective response challenges us to revisit our work in a way that addresses issues of continuity from a dialectical position that values the role of thematic patterns.

As scholars of science education, we believe that research on the apparent conceptual continuities between everyday understandings and scientific understanding represent the tip of the intellectual iceberg. Scholars have challenged how science educators shape pedagogy with respect to language (e.g., Reveles et al. 2004), however, these pieces explore the surface of the relationship between language, identity, and conceptualizing science. The critiques of our work provided us an opportunity to explore this relationship at greater depth.

In attempting to make sense of their critiques, we were able to categorize their appraisal of our research into three primary domains. First, we recognized a series of critiques that claimed our work was limited in its recognition of the decontextualized and situated nature of language. Second, we recognized a series of critiques that challenged the very notion of what counts as understanding. Third, we recognized a series of critiques that challenged how we defined the final goals for teaching science. Although their manuscripts offered additional appraisals, the nature of this rejoinder prevents us from appropriately exploring each of the critiques offered by the reviews. Instead, we will address these three significant critiques.

Decontextualized and situated nature of language

The first major domain of critique involves a general appraisal of our research as being decontextualized and limited in our analysis of how situated learning perspectives impact learning. This critique was generally of two types. First, Hwang and Kim suggested that our work presented a dichotomy between informal and formal discourse. Second, they suggested that our work failed to adequately draw lines of distinction between the relationship between formal and informal science literacy. Hwang and Kim wrote,

> The division of literacy to the formal and the informal is one of the dualistic dichotomies presupposed in Brown and Kloser's approach to their interview data with the student baseball players. Perhaps traditional science education studies on conceptions/conceptual change are deeply grounded in this dichotomy regardless of whether they theorize the informal positively or negatively.

In our attempt to assess this critique, we reflected upon a body of literature that challenges the false divide cast between vernacular and non-vernacular discourses (Brown and Spang 2008). We never intended to communicate a position that suggested that language could be cleanly divided into formal and informal modes. Additionally, we never communicated that we assume that discourse practices can be cleanly divided into formal and informal domains. In fact, we would argue the contrary. We take the position that all language is contextualized and thus, must be understood as a product of the sociocultural frameworks that give them their meaning. As a result, we see the baseball players as acquiring a functional use of highly contextualized word meanings that we contend are potentially useful for learning in the science classroom if we see language as more than merely contextual. More specifically, we are concerned that educators may be unaware of the situated and contextualized knowledge that students bring with them to the classroom because of an educator's being unaware of the conceptual continuities embedded in students' talk.

In this way, terms that have alternative meanings in a broader social context gain new meaning in the context of sport. Therefore, teachers and science educators would benefit form gaining an understanding of how students' language and understanding in an informal context are potentially useful for teaching in the science classroom. For example, the players in our study used terms like "bite," "movement," and "cut" to describe different aspects of a baseball's movement (see Table 1). Generally, bite tends to refer to a cut that is obtained by teeth (noun) or the process of cutting with teeth (verb). Either way, if individuals are to arrive at a common understanding of the word "bite," they must understand the term in the context in which it finds its meaning. In the case of the young men playing baseball, they used the term "bite" to describe instances where a baseball changed directions rapidly. The challenge involves whether or not a science educator understands what linguists argued years ago. The context of the culture of baseball leads to the development of a set of linguistic resources that were created to enable baseball players to describe their understanding of how a ball is moving.

There are, of course, challenges for students developing these linguistic resources. These resources often provide contrary meaning to scientific meanings. A common example of this is found in the vernacular use of the term "force." A base runner may be "forced out" despite having no connections to this player's acceleration or mass. Also, in a baseball context the term "velocity" is used purely to describe how fast a baseball is travelling from the pitcher's hand to the catcher's glove, while a variety of terms like "movement," "bite," and "cut" are used to identify pitches that have both speed and directional movement. The problem lies in a potential conflict that students may encounter because velocity may have an alternate meaning in the academic context. In this way, the

Table 1 Alternative situated/contextualized meanings

Term	Broader meaning	Situated meaning (baseball)
Bite	[bahyt] *verb (used with object)* 1. to cut, wound, or tear with the teeth 2. to grip or hold with the teeth 3. to sting as does an insect *noun* 1. an act of biting 2. a wound made by biting 3. a cutting, stinging, or nipping effect	[bahyt] *verb* 1. to change directions dramatically
Cut	[kuht] *verb (used with object)* 1. to penetrate with or as if with a sharp-edged instrument 2. to divide with or as if with a sharp-edged instrument, server; carve 3. to be eliminated *adjective* 1. that has been subjected to cutting 2. fashioned by cutting 3. reduced by or as if by cutting	[kuht] forms: cuts, cutter *verb* 1. the action of a baseball quickly changing directions *noun (cutter)* 1. A fastball that dramatically moves left and right
Movement	[moov-muh nt] *noun* 1. the act, process, or result of moving 2. a particular manner or style of moving 3. actions or activities of a body of persons	[moov-muh nt] *noun* 1. to have the quality of drastically changing directions

language is situated and contextualized. However, we are concerned about whether or not teachers can recognize the value of students' expressions of scientific ideas without a theoretical framework that accounts for the continuities in potentially different modes of language.

In addition to challenges associated with the contextual nature of science language, the authors suggested we have not considered the situated contexts of communication. Hwang and Kim wrote,

> However, we find that the authors' proposal of the (structural) similarities between the vernacular genres and canonical scientific explanations misses the heterogeneous nature of situated activity. It does not articulate the dialectic dynamics of learning by which students' linguistic performances develop heterogeneously and therefore concretely realize hybridized cultural possibilities of the vernacular and scientific genres. This is so because the authors' analysis of literacy does not fully consider the situated context in which communicative performances are continuously made available and make sense among participants in the conversation; that is, the interview situation in which student baseball players talk about scientific representation (curve ball) in the presence of science educators.

This critique is challenging given the extensive nature of this research effort. Our research project entailed both ethnographic and mixed-method approaches to studying the culture of baseball. Ultimately, the ethnographic component of our study provided us with insight about what language students used to describe phenomena and led us to the design of our research study of students' scientific understanding and language use. In this way, their critique ignores that extensive ethnographic work that enabled us to design the study.

Additionally, studying students' language practices in situ creates an enormous challenge in the context of sport. In classrooms, conversations are highly structured and guided by a teacher. The constraints of having students sitting in seats and standing in assigned laboratory stations makes an in situ analysis of classroom talk feasible. In sports, students are involved in constant movement and often separated into groups that can be as distant as 400 ft apart. Thus, gaining insight into students' explanations in situ is not only difficult, but also not feasible. Additionally, the context of sport involves a great deal of procedural knowledge as opposed to declarative knowledge. Therefore, we needed to create a scenario that placed every athlete in a situation that required them to explain concepts using the language of both science and baseball. The interview format, while not perfect, enabled us to assess how all of the players used language to explain their understanding of why curveballs curved.

Language learning is indeed situated. We agree. However, if by situated one means that the hegemonic practices of science classrooms provide ample room for students to learn the language and content of science, then we will argue that taking that perspective is inadequate in framing how sociocultural issues impact science learning. By situated, we argue that students necessarily develop a dynamic set of conceptual and linguistic resources that are not currently being used by teachers because of science education's limited theoretical and empirical understanding of students' conceptual continuities.

A final critique in this domain involved the suggestion that everyday language use would cause a hindrance to students' understanding. Yeo made this critique as she stated, "While this may be true, such everyday usage of similar scientific terms can also pose a hindrance to science learning. An example is shown in the next two excerpts below." We absolutely agree with this critique, but challenge scholars to consider the alternative. If we merely ignore the idea that students' everyday language resources may be useful in teaching, we exclude the cultural resources of a majority of students. In the U.S., this minority population is quickly growing and is projected to be the majority of potential scientists. We suggest that it is the teacher's role to use everyday language resources in ways that promote student learning. In the past we have conducted quasi-experimental studies that indicate that using everyday language resources to begin instruction can dramatically improve students' learning (Brown and Ryoo 2008).

When is understanding understood

The second major critique focuses on analyzing the understanding represented by subjects' discourse. Yeo defines a two-pronged gold standard for understanding in science education. The first prong addresses scientific language and thematic patterns that represent those of authorities in the respective science fields. Yeo's diagrams clearly depict the differences in complexity and conceptual relationships between science authorities and high school baseball players in relation to the phenomena of a curve ball. In comparing the differences between the diagrams, she raises doubts about the degree to which subjects' responses can be considered scientific. Indeed, this appears to be true, but this analysis fails to recognize two important points. First, Lemke's work on thematic patterns deals with classroom-based science that usually carries with it expectations for students to use scientific discourse and language. Since this study took place in the informal setting of a baseball field one would expect not only different lexical patterns as compared to the classroom, but also different levels of complexity at which one would consider an answer complete. Yeo's comparative authoritative source on the phenomena of a curveball was taken from a source with the expectation of formal, technical language and a complete conceptual description. In this study, subjects were not prompted to use particular language resources, and given the role of the interviewer as both researcher and statistician/coach, expectations for a technical or comprehensive description remain questionable.

Second, and more importantly, Yeo's diagrammatic analysis is based on final outcomes whereas our conceptual continuity framework focuses on student understandings prior to formal educational interventions. From this perspective differences exist, but more importantly, so do congruent parts of the authoritative and novice diagrams. Indeed, subjects' diagrams displayed simpler thematic patterns, but in Yeo's comparison, the subjects' patterns corresponded with, not contradicted those of the expert. This is not to say that if all subjects' descriptions were similarly mapped that contradictions with the authoritative source would not occur. We recognize and state in our data analysis that many subjects either feigned the use of science terminology and concepts or provided clearly inaccurate explanations. However, if teachers could develop ways of recognizing the parts, sequences, and patterns of students' speech that do overlap with those of experts, then this may serve as a foundation on which complete and correct understandings can be built.

The second prong of Yeo's gold standard concerns the generalizability of science knowledge. In other words, can students take the concepts and principles from specific phenomena rooted in the material world and apply it to a new situation rooted in the same concept but containing different agents. For example, a pitcher in our study may understand that the speed of a baseball moving through the air produces different air speeds on the top and bottom that results in differential air pressures (Magnus Force) and ultimately, a baseball that curves. As Yeo suggests, this player may understand this specific phenomena of the material world, but fail to generalize this situation as a specific case of

Bernoulli's principle that applies for other objects moving through fluids. We do not disagree with the importance, perhaps even supremacy, of scientific generalizability. Generalizability represents a fundamental feature of scientific knowledge that allows for and enables both theoretical and practical advances. However, from a science education perspective, acquiring this "gold standard" trait often requires the elaboration of a subject's prior knowledge—best done through interactions with concrete, situated examples.

Yeo also draws upon the generalizability argument when she states, "Unlike the use of abstract terms like "flow velocity" and "spin velocity" in Excerpt 1 (that of the authoritative science voice), the use of concrete terminology such as "ball" and "air" is an indication that the students' understanding was situated in the game of baseball." She suggests that many of the subjects' speech acts remain rooted in the situated context of baseball and fail to exhibit abstract properties. We do not argue that these examples provide little evidence for generalized science knowledge, but in light of the interview protocol it does not logically follow that subjects *could not* generalize or use abstract scientific language and concepts in their descriptions. Since subjects were asked questions like, "Tell me how a curve ball curves" or "describe what makes a baseball curve" in an informal baseball practice setting, subjects naturally articulated most descriptions in the situated language of the activity in which they were engaging. That some subjects did speak abstractly and others did not may be more of a function of the interview situation than an indicator of subjects' ability to generalize.

The existing data prevents one from knowing for certain the ability of subjects to generalize scientific knowledge because the study did not focus on the baseball players' abilities to abstract or transfer knowledge. This would have required further tasks posed to the subjects that involved an object moving through a liquid and specific directions to describe the phenomena using generalized, scientific knowledge. Indeed, most transcripts lacked elements that were articulated by the authoritative science source in Excerpt 1. For example, Yeo identifies one subject who fails to mention the connection between the abstract concepts of air pressure and force—a crucial missing link between the subject's description of "different airs" and "[the] ball drop[ping]." If, however, we only recognize the missing elements required for complete understanding, we would neglect important information that would be helpful during an educational intervention. The conceptual continuity framework suggests that subjects possess partial understandings and lexical resources upon which teachers could begin to build understandings that in time could lead to the "gold standard" of science education. Thus, our conclusions focus not on whether high school baseball players possess complete understandings and the ability to generalize due to their participation in baseball, but rather that within these incomplete understandings and situated language, teachers might best facilitate learning by recognizing these continuities. As a result, we now recognize that without a theory that adequately employs linguistic relativity and recognizes continuity, our current assessment and pedagogical approaches are limited in their ability to recognize what students really understand.

A focus on the final product

The third major critique involved the authors' analysis of the final goal for science teaching. Both Hwang and Kim and Yeo's analyses of our research challenged how science educators would define the ultimate goal for learning if we include the conceptual continuity perspective. Yeo suggested that scholars should not drift away from the ultimate goal of helping students understand science terminology as she wrote:

> In other words, whereas everyday language may be able to convey certain scientific ideas as interpreted by us teachers, it is important to introduce the *correct terminologies* to the students when learning science since the same words can have different meanings in different contexts.

We agree that the end goal is to help students learn to use and understand the science language. We argue that if we do not make affordances to recognize the resources students bring, we leave issues of language learning as a subtext of learning that divides the classroom on cultural lines. Thus, we are not challenging the end goal of science teaching; rather we are challenging the pathways towards arriving at those end goals.

Yeo further challenges our conception of the end goal suggesting that perhaps the "gold standard" for science learning is too high. She explained:

> The result of these gold standards held by science teachers could be the reason for the alienation students feel towards science. Reading Brown and Kloser's paper led me to wonder if these gold standards are made too high for many students, especially those non-achievers in science, to attain. If we were to lower the standard, what is our tolerance level and what is the implication towards science literacy?

We maintain the high standards of science education, but hope educators will consider arriving at those goals in a different fashion. We do not believe the goals should change, rather, we believe that students are not provided appropriate access to science. If from the start we only accept the "gold standard" in a student's science education then we will continue to fail students who are not members of the privileged mainstream communities. We must work toward this gold standard as the ultimate goal and thus, our paper challenges the ways in which science educators currently attempt to reach this goal. We are challenging science educators to prepare teachers to recognize the conceptual and lexical continuities between students' understandings and those that are valued in the classroom. The students in our study are considered non-achievers who are participants in one of the lowest performing school districts in the United States. However, we contend that reconsidering our perspective on knowledge and language in science education has the potential to make the invisible visible.

Final thoughts

Once again, we thank Hwang and Kim and Yeo for their thought provoking critiques that helped us engage more deeply the idea of conceptual and lexical continuities in students' science discourse. While most of our response addressed shortcomings articulated by the above authors describing what conceptual continuities *are not*, it may prove helpful to close with aspects of what conceptual continuities *are.*

Whether formal or informal, situated or abstract, conceptual continuities recognize seeds of understanding embedded in student discourse. Much like diSessa's (1993) *p-prims*, conceptual continuities focus specifically on the linguistic resources that students use to convey these partial understandings. Ultimately, the continuity framework represents a way for teachers to address alternate or incomplete understandings in the classroom; alternate or incomplete understandings that may exist for all students, but due to varying relative language resources may not be used to generate complete understandings. We certainly agree with Yeo's statement that, "The degree of science understanding the students had displayed in their talk is merely scratching the tip of the iceberg in understanding science," but we see the tip of the iceberg not as a miniscule, but rather, powerful force for change. Like any good cruise or oil tanker captain who never underestimates the impact of the iceberg's tip, teachers must also recognize students' seeds of understanding vis-à-vis their lexical resources and then build on these to generate complete, generalizable conceptual understandings.

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