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Moving Past Curricula and Strategies: Language and the Development of Adaptive Pedagogy for Immersive Learning Environments

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Abstract Given current concerns internationally about student performance in science and the need to shift how science is being learnt in schools, as a community, we need to shift how we approach the issue of learning and teaching in science. In the future, we are going to have to close the gap between how students construct and engage with knowledge in a media-rich environment, and how school classroom environments engage them. This is going to require a shift to immersive environments where attention is paid to the knowledge bases and resources students bring into the classroom. Teachers will have to adopt adaptive pedagogical approaches that are framed around a more nuanced understanding of epistemological orientation, language and the nature of prosocial environments.

Keywords Language in science · Immersive learning · Social negotiation · Epistemic engagement

As we begin to look to the future of science education research, a key question to be considering is why have we had such little success thus far in shifting the nature of science classrooms? What are we missing? Will the community make considerable strides in the coming decades or simply float idly along making little practical gains in schools? In this article, we argue that future work needs greater commitment to nuanced aspects of classroom environments, language and teachers' epistemic positions. At first glance, one might simply bypass our argument as a reiteration of social learning theory. We make the case, however, that the science education research community engages in rhetoric without truly acknowledging

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the nuances of the perspective—similar to pre-service and in-service teachers' use of student-centered inquiry language without internalizing and enacting pedagogy that reflects it. Specifically, we target three areas in which nuanced aspects are not fully reflected in the current literature (i.e., classroom environment, classroom dialogue, and teacher beliefs and practice), which thus serve as key areas for future growth in the science education research community.

Immersion and the Need for an Epistemic View of Language

We know that language is fundamental to science and science learning. Language access, use, and representation is changing among young people as they engage and create with new media platforms. For example, within the past 20 years, there have been incredible shifts in the forums for social interaction—toward individualized yet social platforms and activities. Students create these environments, create their own personalized spaces (e.g., facebook profiles and groups, webpages, and music playlists), and find information from a multitude of sources in a manner very different than traditional ways in which people interact with media. These trends are infiltrating the natural sciences with platforms being utilized that allow for greater flow of information and exploration of questions that stretch the imagination, illustrate the amazing capacity of human creativity, and leverage human resources across the globe. While we see these advances toward autonomy, social interaction, and collaboration as a positive movement, they raise challenging questions for science classrooms and science education researchers. To what extent do and will schools reflect this new norm? What are the characteristics of pedagogy that must evolve with this changing landscape? What resources will teachers need to draw on to enact future pedagogies? Do current stances and recommendations of best practices from science education researchers go far enough to meet the needs of future students?

We see these questions as critical to the future of science education. Considering that many students already perceive a substantial gap between their everyday life and school science, failure to evolve only widens the gap. For the research community, continuing to follow at a distance will expand this gap and serve to disenfranchise more students—particularly those not trained in the game of schooling. In this article, we propose a vision for science education that moves past curriculum and strategies toward immersive environments requiring adaptive forms of pedagogy that dynamically respond to students' desires to create and to be treated like intelligent beings. Students need to be provided with opportunities to be partners in the learning process rather than be on the receiving end of the learning process.

Central to a transition toward immersive science education experiences is language—particularly how it is leveraged and who leverages it in the classroom. The focus on language is essential because there is no science without language (Norris and Phillips 2003). Science as a discipline does not exist without language—this includes all forms of language, e.g., text, picture, graphs, equations, and other symbol systems. However, it is the orientation to language that we believe needs to be addressed as a critical shift in how we approach language use in the future. The work of Halliday and Martin (1993) has been very influential in science education where there has been more attention given to the results of the language task (the product) than how the product itself is generated (the process). For Halliday and Martin, there is a need for students to learn the genres of science before they actually use them. For example, it is important for students to know the parts of the laboratory report and the language requirements for each before they actually get to use it. This approach to language use has certainly influenced much of the work done in argument-based inquiry (Cavagnetto 2010).

However, we believe that Halliday's earlier work is more appropriate as it connotes the idea of immersion. Halliday (1975) suggested that the best approach to learn about language is through using the language as you live the language. Language is not learnt separately from its use—the approach to learning language is by being immersed within it. Language becomes an epistemological tool (Kelly et al. 2000) in which students learn the language of science as they learn about the disciplinary knowledge of science. In other words, without language, students cannot be involved in learning science; thus language itself becomes a tool through which students are able to come to know science better. This perspective of language is the underlying basis of an immersive approach to learning science.

Building on work from other disciplines such as foreign language education, where there is a strong emphasis on immersion (Cummins 1998), we believe that there is a need to place emphasis on providing opportunities for learners to learn the new language of science by being immersed in environments where that is the language of instruction. To maximize the use of language as the epistemological tool underpinning science, learners have to live the language of science as they learn about the language of science (Norton-Meier 2007). This means that to be fully immersed in learning science, and be engaged in all the epistemic practices as outlined by the recently released Next Generation Science Standards (NGSS Lead States 2013), learners have to live these practices—they cannot be taught these practices separate to their use. The construction and critique of science knowledge by students is not achieved through information transfer. To understand how science knowledge is constructed students need to experience the multi-dimensional processes involved in their own construction of this knowledge.

Scientists advance conceptual knowledge by engaging in argumentative practices. That is, scientists are immersed simultaneously in both argumentative practices and knowledge advancement. This is what is required within science classrooms—this is what we mean by immersion. Students' understandings of science are generated through engagement in argumentative practices as critical tools for learning the science concepts. The driving principle is that these two essential elements (knowledge advancement and argumentative practices) are not advanced by information transfer, or by separating them, and a pedagogical shift is required that recognizes that essential role of language as an epistemological tool.

An important shift in research efforts (Prain 2006) has been to focus on a much richer definition of language, moving beyond text, either verbal or written, to include the broad range of representations students have to engage with in the current and future technological age. These increased representational opportunities mean that students have demands placed on them to communicate more broadly than simply reporting to the teacher—thus requiring a new perspective of the role of language in science learning opportunities. This shift in focus to build immersive experiences in language will require a different view of pedagogy, the promotion of dialogue and the development of clear alignment between how teaching is practiced and the way in which we believe learning occurs. It will require the adoption of adaptive pedagogies that truly align student learning, argumentation practices, language practices and classroom environments. Toward this end, we see two broad aspects needed to support the evolution of science education: (a) a shift from traditional static, inflexible reasoning models toward a dialectic model of reasoning, and (b) a shift from a deficiency-perspective toward a resource-perspective of students and classrooms.

From a Static Reasoning Model (Toulmin) to a Dialectic Reasoning Model (Walton)

The focus of many researchers over the last 15 years has been on the use of argumentation practices within science classrooms and how we can provide opportunities for students to participate in these practices (Duschl 2008; Osborne et al. 2002). This work is reflected in recent reform documents, which place a great deal of emphasis on student engagement in the epistemic practices of science. A central component of these practices is for students to be able to "grasp the practices" of science (Ford and Forman 2006). For Ford and Forman this means that students need to be able to both construct and critique knowledge as part of being involved in scientific practices. However, they raise serious questions about the ways in which argument is viewed, and a lack of success in getting students to actively partake in critique.

There are a number of critical issues that we believe are important in helping students grasp the practices of science. These include: (a) students are not scientists, (b) the orientation to a process-product approach in terms of language use, and (c) the philosophical orientation to argument. In terms of students not being scientists, there is a need to examine what is it meant, and achievable, by grasp of practice. We would argue there is much confusion in terms of how much students should be able to do. For us, *practice* refers to school children being able to engage with the relevant epistemic practices of science. Can they pose questions, design experiments, gather data, and generate claims based on evidence? The answer should be yes. Will they have the knowledge of scientists? No. Will they have the expertise of scientists in implementing these practices? No. Can we help them build understandings of how arguments are constructed and debated? Yes. In part, this is a separation between knowledge of the science concepts and knowledge of the practices used in constructing and critiquing these concepts. This distinction is not trivial.

The central role of language is critical when examining the particular approach to use in helping students have success in grasping these practices. Much of the research in science education on argument has been framed from a Toulmin perspective of argument. Toulmin's pattern of argumentative reasoning emphasizes traditional, fixed forms of logic where the person framing the argument needs to account for claims, evidence, backings, warrants and rebuttals, as well as to ensure counter arguments are engaged with. The research has often focused on either providing explicit instruction in the components of argument (Osborne et al. 2004) or on analysis of student argument as an outcome of inquiry. However, Duschl (2008) states that students "bring a great deal more to argumentation than are identified by strict logic or rhetorical schemes like Toulmin's Argument Pattern" (p. 172). He argues that there needs to be a shift "from an emphasis on deductive and inductive argumentation schemes to an initial emphasis on the more natural dialogue logic found in dialectical contexts" (p. 172). Focusing on Toulmin's logic structure creates a dialogical emphasis on using the language correctly as opposed to a dialogical emphasis on knowledge constitution, thereby neglecting decades of language-to-learn research.

An alternative perspective of argument is offered by Walton (1996). According to Walton an argument is any logical contribution to an unresolved issue. Walton offers this somewhat generic definition in an effort to capture the dialectic nature of argument. That is, the logical strength of an argument is context dependent. The movement from a strict Toulminian perspective toward the dialogic illustration of argument championed by Walton may appear subtle, but we see this as a fundamental shift in the nature of classrooms—one that opens the door to adaptive pedagogy. Central to adaptive pedagogy is the idea of *negotiation*.

Negotiation captures both public forms of negotiation, in which parties try to reach a mutually agreed condition by both articulating and critiquing various positions, as well as private negotiations in which an individual engages in personal reflection on information from the external environment with his/her existing position. We see the idea of negotiation as intimately connected to the construct of argument. Critically, we do not simply see this as negotiation of science knowledge—there are a number of different knowledge bases that are being used and engaged with in an immersive environment.

From a Deficiency Orientation to a Resource Orientation

In science education much of the work in the eighties and into the early nineties was focused on identifying students' misconceptions (see Pfundt and Duit 1994). Much work was dedicated to determining what knowledge students brought into class with them and how aligned that knowledge was to the correct scientific version. This resulted in the development of classroom instructional approaches that would help students understand the correct science concepts. While as a community of researchers we have studied in much detail what student-centered classrooms should be like and how effective they can be, we are still seeing science classrooms focused on information processing—the need to cover curriculum, enact particular strategies, and ensure students "get" the right answer, so as to ensure successful performance on standardised tests. As such, teacher preparation programs and professional development focus largely on routine expertise in pursuit of successful delivery of the content—with the ultimate goal of helping build students' knowledge in a manner that overcomes their deficiencies in understanding.

However, we believe there is a need to shift the perspective to focus on what resources students bring into the classroom and use as the building blocks of the learning environment. In an immersive environment students are engaging knowledge bases such as knowledge of science concepts, knowledge of argument and argumentative practices, knowledge of how to use language, and knowledge of negotiation as a critical element of learning. At the same time, students come into the learning environment with their own particular cognitive, linguistic, and representational resources. These knowledge bases and resources are not engaged separately to each other. For example, there has been much work done by researchers in the area of using language as a learning tool (see the work of Norris and Phillips 2003; Prain 2006; Yore and Treagust 2006) that has clearly shown learning of science concepts cannot occur without engaging language—and understanding of both is advanced simultaneously, as each of these knowledge bases is used simultaneously.

Given that each of these knowledge bases and resources are being brought to every learning situation, we need to shift our frame of reference in classroom learning environments from what students lack to what they have. In immersive classrooms students are not only negotiating the science concepts as part of the argumentation process, they are continually negotiating with all their knowledge bases as they commit their cognitive, linguistic and representational resources to the task. By recognizing and building from these resources, we believe that students will be able to have entry points into the learning situation rather than feeling deficient about what they do not have. This will require a shift in the epistemological and pedagogical orientations that teachers need to have in order to be successful in these immersive, argument-based inquiry environments.

The broad shifts toward a dialectic view of language and a resource perspective require that we reconceptualise the nature of classroom environments, classroom dialogue, and teacher beliefs and practices; thus we see these as critical areas for future research in science education. As argued above, language is central to immersion and how students choose to engage with the language and one another can mediate the quality of the immersive learning experience. Below, in Critical Area I, we argue that in order for immersion to be realized, more attention must be paid to the role classroom environments play in supporting student engagement in public negotiations. This work builds on recent studies acknowledging the considerable influence that context plays on student engagement. In Critical Area II, we contend that students draw on knowledge bases during engagement in both private and public forms of discourse. As with the environment, we see students' integration of these knowledge bases as potentially significant mediators of learning in immersive environments. Lastly, we acknowledge that a teacher's beliefs and practices influence the nature of the classroom environment and dialogue (e.g., level of autonomy, what is valued, norms for dialogue, etc.); therefore the immersive learning experience. Thus, in Critical Area III, we highlight the need for teacher alignment of their epistemic orientation, knowledge bases, and pedagogical practices in order to realize immersive learning experiences for their students.

Three Critical Areas for the Future

Critical Area I: Shifts in Classroom Environment

Key to shifting the classroom environment from what students lack to what they have is recognizing and accessing the resources that are available in the classroom—in particular, the often under-utilized human capital available in science classrooms. Recent work has begun to shift the conversation away from a deficiency perspective toward greater emphasis on the task or classroom context as being particularly influential to classroom interaction and communication (Berland and Hammer 2012; Felton et al. 2009; Gilabert et al. 2012; Moje et al. 2004). For example, Berland and Lee (2012) found that social pressures can influence the nature of argumentative discourse. Specifically, they found that one important factor was students' ability to save face. That is, legitimization of the various student perspectives allowed groups with diverse perspectives to move toward consensus. Similarly, a recent case study suggests that students' and teachers' framing of the task influences task engagement (Berland and Hammer 2012). The frame or "schema that organizes past experience" of the task influences students' perceptions of task purpose and norms (p. 87). That is, the frame influences what they see as important for task engagement. Building on these findings, we argue that how students view the task also influences the extent to which they access others' ideas during the task.

Similar to others (Jimenez-Aleixandre et al. 2000), our own work illustrates that simply getting students to argue is not necessarily leveraging the human capital in the room, because students often talk past each other as they seek to complete the task (Cavagnetto 2010). A critical construct to more effectively accessing human capital is epistemic vigilance. Mercier and Sperber (2011) contend that during an argument, individuals engage in epistemic vigilance—a quality control process to decrease the likelihood of being misinformed or misled. They argue that a receiver initially considers the character of the informer—Are they trustworthy? Do they have the appropriate credentials to be informative on the subject matter? If deemed trustworthy, the logic of the information is checked against what the individual already understands about the subject matter. In essence, epistemic vigilance is reasoning during an argument. We expand on Mercier and Sperber's idea of epistemic vigilance to inform our view of reasoning in a scientific context (see Fig. 1). In authentic science contexts, trust calibration and coherence checking inform and are informed by the epistemic practices of science. So students are not only checking the rhetorical structure of the argument, they are doing so in addition to evaluating the rigor or quality of method from which the evidence was generated. We see this as a critical point, because like recent reform documents (NRC 2012), it emphasizes the relationship among rhetorical logic and rigor of scientific practice.

A Toulminian perspective focuses on the logic structure central to the coherence checking process of epistemic vigilance; thus much work in science education has concentrated on the coherence checking aspect of argumentative reasoning. Only recently have studies in argument in science education contributed to the exploration of trust calibration (e.g., Berland and Hammer 2012). Importantly, the work that has been done thus far emphasizes task purpose and how the task is framed by the teacher and students (i.e., as consensus building or as persuasive). While we acknowledge that this moves the field in a positive direction, we would suggest that the framing of the task, and similarly cooperative learning activities, do not go far enough when we look to the future. First, they do not explicitly emphasize the importance of one's vigilance to scientific practices. The emphasis is on increasing the quality of interactions. Further, and perhaps more importantly, work on cooperative learning and consensus building argument activities focuses on *strategies* for increasing student interaction in specific activities. What percentage of classroom time do these activities occupy? How much human capital is not being leveraged during the other time in the class?

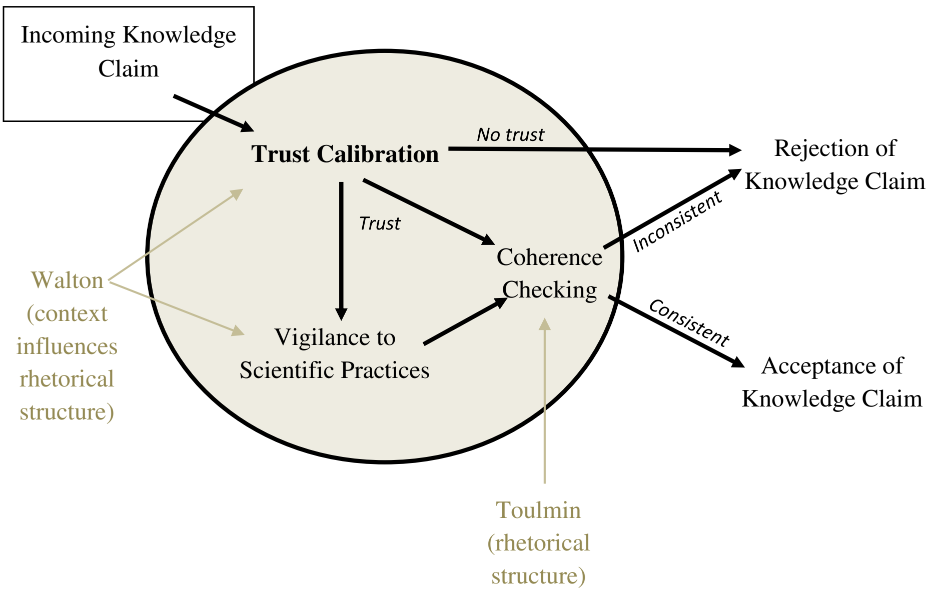

Fig. 1 The process of epistemic vigilance as an essential function of argumentative reasoning. Toulmin's reasoning pattern focuses on the logic structure central to coherence checking while Walton, in recognizing the dialogical nature of argumentative reasoning, acknowledges trust calibration, vigilance to scientific practices, and subsequently coherence checking

We are arguing for a pedagogical approach that pushes beyond individual strategies toward a classroom culture of altruistic collaboration. By this we mean an approach to seed an environment that moves students from an individualistic perspective toward a view of themselves as agents for the greater good (see Fig. 2). Thus, we see an important next step as movement toward the development of *prosocial classroom environments in science contexts*. This is more than adoption of a socio-cultural or social learning perspective. While it does align with these perspectives, we see this as a step past collective sharing of resources toward a more cooperative view of the individual within the greater group. Importantly, we stress that we do not yet fully understand how the group as a collective impacts individual student learning, how individuals see themselves as part of the prosocial environment, and how different contexts impact the development of such environments, yet there is considerable evidence across the social and natural sciences that groups, particularly those that are altruistic, outperform individuals (Caprara et al. 2014; Mercier and Sperber 2011; Wilson 2007).

Selecting for Prosocial Ecosystems

A number of studies across psychology and anthropology suggest a group bonus effect, where groups of individuals are able to solve problems that members could not solve independently (see Mercier and Sperber 2011 for a concise review). This trend of altruistic groups outperforming individuals and non-altruistic groups is documented across numerous natural systems as well. For example, cooperative insects make up most of the biomass of all insects, multicellular organisms arose from cooperative single-celled organisms (Wilson 1980, 2007). Schools commonly create atmospheres that select against prosocial mindsets—with students oftentimes holding mindsets closer to the individualistic end of the prosocial spectrum. We recognize that a purely altruistic environment is not likely to be achieved; however, movement from the individualistic end of the continuum toward the altruistic end may provide considerable gains (both psychologically and academically) at relatively low cost.

An environment in which students engage in self-sacrifice for the betterment of the class may seem idealistic, particularly as we enact the common trope *survival of the fittest*—connoting individuals act only toward their own best interest. However, group selection is possible by increasing the selective pressures acting at the classroom level relative to those pressures acting on individuals (Sober and Wilson 1998). That is, in any environment, there are pressures that influence all levels of the system. For example, in a school district there are pressures that act on the district as a whole (e.g., state funding), individual schools within a district (e.g., socio-economic status of the neighborhoods served), grade levels (e.g., state mandated testing for science at grade 5 influences the amount of time spent teaching science), at the individual classroom level (e.g., make up of an individual class can influence the relationship that a teacher has with a class), and on individual students within the classroom (e.g., a student's prior experiences, home life, physical and emotional resources outside of school). We contend that while school systems have pressures across these various levels,

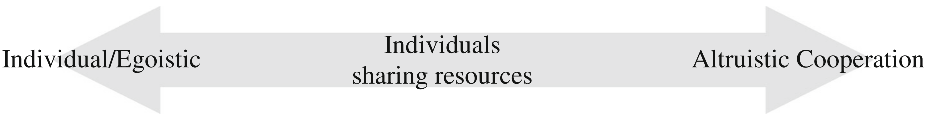

Fig. 2 Continuum illustrating various degrees of prosociality. Pressures continually act on multiple levels of school systems; one's position on the continuum is not fixed

within classroom pressures tend to be the primary pressures that students feel. As such, selection acts within the classroom—on individual students—leading them to respond and make decisions as individual students instead of a cohesive, collective, single classroom *organism*. This has implications for resource access, because from the egoistic or individual perspective, students will essentially default to actions that they see as beneficial only to themselves in the short term. As such, one is less likely to take time and energy to engage with others' ideas or help another student. Indeed we have documented this in previous work as elementary students engage with one another to espouse their ideas, but fail to take time to consider other ideas—essentially student dialogue exists, but students simply talk past one another as they generate explanations in order to efficiently complete their portion of the task (Cavagnetto 2010). Like others (Kuhn et al. 2013), we found that the nature of the task as collaborative can mediate this effect.

There are examples of movement toward greater prosocial environments with group-level selective pressures. Ostrom's (1990) Nobel Prize winning work on societal uses of common pool resources identified eight characteristics of effective groups that were later generalized to other systems (including schools) by Wilson et al. (2013). The eight selective pressures include:

- Clearly defined group boundaries—strong group identity
- Proportional equivalence between costs and benefits
- Collective-choice arrangements
- Monitoring
- Graduated sanctions
- Conflict-resolution mechanisms
- Group autonomy from the larger system—ability to conduct own affairs even when part of a larger system
- Coordination of relevant groups for groups that are a part of a larger social system. (p. 22)

Importantly, as Wilson and colleagues point out, these design principles are not an exhaustive list. Wilson et al. (2011) used these principles as an intervention in a school within a school program in upstate New York with the goal of creating a more prosocial classroom environment. While no other pedagogical intervention was enacted, students who in the previous year had failed three or more high school courses performed at the same level as the average high school population in the school district on all state examinations.

We have just begun looking at the potential relationship between group selective pressures and learning; however, our initial analysis of videos indicates the presence of some of the design principles:

- Strong group or classroom identity
- Student autonomy and decision making
- Student monitoring of group norms
- Student mediation of disagreements
- Norms that emphasize the evaluation of ideas as opposed to evaluation of personal characteristics.

While classroom identities were defined, monitored and mediated in both high and low implementing classrooms, these acts were carried out by *the teacher* in the low implementing classrooms and were the purview of *the students* only in our highest implementing classrooms. That is, students in the high implementing classrooms engaged in collective decision making to the point of having true ownership over the actions and management of the classroom activities. In one classroom it was common for the teacher to begin the class by asking students, "What did we figure out yesterday?" and on hearing multiple responses from students she would query, "OK, sounds like we made some good progress, so what does that mean for today?" The prompts from the teacher were natural, obvious, and conversational. The teacher shifted from pre-planning conversations to engaging in authentic conversations around collective problems of scientific practice. While teachers often think that such adaptive pedagogical practices are more labor intensive, requiring the planning of many potential pathways, the instructional planning actually becomes less laborious because the questions are everyday questions—What is an important question for us to explore? What is the best way to figure that out? What is the best way to represent our observations? What can we claim? What evidence do we have to support our claim? While planning time is reduced, the instruction itself becomes more demanding because the teacher must truly be present, listening intently, during classroom discussions.

From this multi-level selection (MLS) perspective, a pathway toward a prosocial classroom environment exists—increasing the pressures acting between classrooms relative to pressures acting within classrooms. Importantly, we believe multi-level selection as a theoretical position provides a unique advantage over traditionally utilized frameworks in education. While we recognize that the teacher has a legal responsibility to manage behavior in the classroom, MLS theory appropriately recognizes that when it comes to learning, teachers only have control of the external classroom environment. We see this as a subtle yet important point as it fundamentally requires movement away from the dominant knowledge transfer role of the teacher, and subsequently has the potential to support the community's movement past curriculum and strategies. Again, while many science education researchers would suggest that a social learning theory lens also requires such a position, the fact is that we continue to emphasize curricula and strategies under the guise of social learning theories and neglect taking the next step toward adaptive pedagogy.

Critical Area II: Shifts in Classroom Dialogue

Dialogue has been interpreted in varied ways by different science educators based on their theoretical orientations, empirical experience, and research agendas. While some scholars identify dialogue as interaction in which students cooperatively construct knowledge in a joint conversation (e.g., Chi 2009), others use the word to emphasize the process of idea sharing and sense making (Berland and Reiser 2009; Jimenez-Aleixandre et al. 2000). Building on the prosocial perspective, we argue that the ultimate goal of dialogue in science classrooms is not only to interact/exchange ideas and persuade others, but also to establish an agreement where teachers and students work together as a community to search for deficiencies in their arguments through solving cognitive conflict utilizing language as a learning tool. As such, language is viewed as being much more than verbal text. Writing is also an important mode of dialogue: "because writing is often our representation of the world made visible, embodying both process and product, writing is more readily a form and source of learning than talking" (Emig 1977, p. 124). Furthermore, it is not simply the documentation of speech as it includes knowledge of idea construction and critique (Galbraith et al. 2007). Thus, the function of writing is not just to translate what students think about the science topic into a written document for the teacher. It also serves to help students construct, represent, and evaluate their knowledge. Building on this perspective, research is now focusing on engaging students across multiple modes (e.g., pictures, models, and equations) that are used within classrooms. For instance, when teachers and students discuss the concept of heat transfer, they should know how and when a line graph is an appropriate representation of a pattern or for generating evidence, or whether percentages of temperature loss provide different evidence from a graph. In this sense, it is necessary to employ different modes to represent their emerging understanding for constructing and critiquing knowledge (Waldrip et al. 2010).

To develop a fluid, lived use of language in science, there are three characteristics of dialogue that need to be emphasized: (a) social negotiation, (b) epistemic engagement, and (c) synergic use of talk and writing. These are explicated below individually, although it is important to recognize that they are interdependent.

Social Negotiation

Social negotiation is a form of dialogue that goes beyond interaction and exchange as it includes cooperation and movement toward mutually accepted positions (Rahwan et al. 2004; Tsai 1999; Walton and Krabbe 1995). In science contexts, there are often strongly held oppositional views making it challenging to reach mutually accepted positions. Ironically, as Ford (2012) notes, critique is the essential ingredient scientists use to reach consensus.

> Typically, knowledge claims are not immediately accepted, and critics provide specific reasons for rejecting their acceptance in light of the aims of the scientific endeavor, reasons that zero in on possible flaws in the warrants or evidence supporting the claim. The author of the claim then sets to work specifically on those flaws. When the flaws are removed and no more can be identified (and of course, the claim represents progress in understanding), the scientific community accepts the claim as certified scientific knowledge. (p. 211)

From this perspective, dialogue in science classrooms is critical for social negotiation through the interplay between construction and critique of knowledge claims. Mercier and Sperber (2011) suggest that focusing on social negotiation supports students to formulate arguments and defend them from objections. In this regard, the function of dialogue in science classrooms is not only to infer and construct knowledge, but also to argue and critique knowledge to advance others' arguments that are valid to the community.

Yet, engaging students in this social negotiation perspective of dialogue is not easy. Duschl (2008) argued that students should not only engage in ontological practice about "what we know" (e.g., facts, theories), students also need to be epistemologically immersed in the practice of "how we know" and "why we believe" (e.g., explanation, justification, evaluation). Hence, such dialogue should focus on the generation of data patterns to form evidence for the support of a claim (Sandoval 2003), the judgment of opposing arguments based on evidence (Berland and Reiser 2011), and the revision and development of conceptual understanding from the epistemic engagement (Kuhn et al. 2013). This cannot be done in isolation, i.e., at the level of the individual. It requires engagement in a classroom environment that truly moves to a prosocial environment where human capital is leveraged throughout the process to continually refine ideas (and simultaneously rhetorical and reasoning abilities) and ultimately build consensus.

Epistemic Engagement

In number of recent reform documents, we see greater emphasis being placed on epistemic practices, for example, the eight practices outlined by the Next Generation Science Standards (NGSS Lead States 2013). Epistemic engagement involves students' understanding and practices of why and how scientific knowledge develops. Students should be involved in understanding the reasons behind knowledge. Thus, the importance of epistemic engagement is placed on the transition *between* data, evidence, and models. Transition from data to evidence requires students to analyze and search the data points for certain coherent patterns (Park and Chen 2012) through application of reasoning skills, such as deduction, induction, abduction, cause to effect, analogy, etc. We believe that Walton's perspective is critical and different to some current versions of argument-based inquiry that focus on such structures as claims, evidence and reasoning where epistemic confusion between data, evidence and reasoning are promoted. Both Duschl (2008) and Nussbaum and Edwards (2011) have argued that we should move beyond the current view of structured dialogue toward a perspective that reflects how evidence is shaped.

Synergic Use of Talk and Writing

Norris and Phillips (2003) have argued that talk is necessary, but not sufficient, to learn and do science while Yore and Treagust (2006) have argued that the relationship between questions, claims, evidence, and modes needs a record (written product) in order to search for patterns and move toward resolution of claims and evidence. Yet, research to understand the value of dialogue has disproportionately examined talk—there has been little attention paid to the critical role of writing. Further, despite the different functions of talk and writing recognized by several researchers, there still remains a limited understanding about how the different cognitive functions of talk and writing are used in a complementary manner to support students' knowledge development in dialogue-rich environments. We advocate that talk and writing should not be used separately, but that the two epistemic tools should be used interdependently. From this perspective, we propose two significant patterns of talk and writing to foster students' development of knowledge and dialogue in future science classrooms: (a) the use of talk and writing in sequence and (b) the use of talk and writing simultaneously.

The use of talk and writing in sequence means that students complete one language task (talk or writing) and then complete the opposite language task. For example, in most cases students will be involved in either small group or whole class discussion before moving onto an individual reflective writing task. Rivard and Straw (2000) suggested that "writing may only work as a heuristic if talk precedes it" (p. 588). They, and Rivard (2004), have directly investigated the effect of the use of writing following talk in eighth-grade science classrooms. They found that talk in conjunction with writing has a greater effect on students' achievement than talk alone and writing alone. This finding may be explained by the roles of talk and writing—talk taking a primary role in sharing knowledge while writing more aptly allows for deliberate manipulation and consolidation of knowledge (Hand et al. 2007).

Simultaneous use of talk and writing is also powerful. Concurrent use of talk and writing creates a shared dialogic space for students to visibly contemplate alternative arguments and undertake reasoned evaluation and critique (Mercer et al. 2010; Warwick et al. 2010). This view is supported by van Amelsvoort et al. (2007) who contend that peers' critique of students' written arguments helps students become immersed in the process of using argument to develop their conceptual understanding of reasoning skills. In this sense, writing is not only more complete but also socially distant because of the opportunities it allows for a writer to revise and make individual products, as a function of their involvement in the group work, more publicly accepted. This kind of writing associated with talk immediately “freezes” students’ ideas on paper to allow for them to be more richly negotiated. A recent study by Chen (2011) supports the value of promoting simultaneous use of talk and writing over a sequenced approach. Importantly, in this study, students began to incorporate different modes into their evidentiary explanations.

Critical Area III: Shifts in Teacher Beliefs and Practice

Changing classroom climates and perceptions about dialogue and the epistemic role of language requires a shift in teachers’ epistemological orientations and subsequently their pedagogical practices. To immerse students in a dialogical learning environment, we suggest two critical elements that require considerable attention: resources that students bring to the learning environment and language that they use as an epistemic tool. These elements require teachers to take on new and different roles in implementing adaptive pedagogy because they necessitate the creation of learning environments where students use the various resources and knowledge bases they bring to the learning environment while engaging in productive dialogue as a function of the epistemic use of language. This means that we have to reconceptualise some of the ideas about teacher beliefs and practice that have previously been engaged with in the literature. In particular, we need to conceptualize what teachers’ orientations to learning are, and how these align to what they should know and be able to do in order to make changes necessary to shift away from traditional teacher-dominated instruction and toward an immersive approach to argument-based inquiry.

Outcomes of current research efforts identify three important aspects that teachers need to develop for successful implementation of argument-based inquiry: (a) epistemological orientations, (b) specialized knowledge for argument and argumentation, and (c) instructional practices. First of all, to effectively incorporate argumentation into science instruction, it is suggested that teachers need to shift their epistemological orientations to be more aligned with key ideas of argument-based inquiry. We believe, however, that there is a need to broaden this current perspective. In the future we believe that a more nuanced understanding of epistemological orientations needs to be engaged with. While the three aspects have been proposed from research we suggest that there is a lack of engagement in how these are serving as epistemological tools.

Importantly, as described in a previous section, there are multiple knowledge bases that teachers and students use. Each of these knowledge bases are underpinned by an epistemological orientation that does not separate the process from the product, that is, use of language and argument within a prosocial environment is predicated on each of these being an epistemological tool with an associated knowledge base. For implementing an immersive approach, teachers, in developing adaptive pedagogy, are first required to adopt a much richer nuanced understanding of contemporary learning theories that emphasize students’ knowledge construction through social interactions, importance of prior knowledge, and students’ capability and responsibility for their own meaning making (Hand et al. 2009; Oral 2012; Windschitl et al. 2008). A rich understanding of learning stresses that only students can control and take ownership of their learning, that is, learning is regulated by students themselves not by the teacher

(Bransford et al. 2000). Without a paradigmatic change toward this view, teachers often struggle to enact adaptive pedagogy that supports students to actively pose questions, generate claims, and assess evidence in publically negotiated ways using a variety of language modalities (Hand and Norton-Meier 2011; Lotter et al. 2007).

With respect to teachers' understanding of what science is, more emphasis should be placed on the importance of critique of ideas in addition to construction of ideas as core practices of science (Ford and Forman 2006). To understand that scientific ideas are represented, communicated, and validated by the community of scientists through argumentation (Sampson and Blanchard 2012), students need to experience such processes. We would argue that currently there is insufficient emphasis on the epistemological function of argument to advance science; while there is construction of scientific knowledge, these are not separate. To this end, teachers are required to simultaneously immerse students in practices of construction, critique, and conceptual growth. Central to this pedagogical approach is teachers' understanding of the reciprocal nature of science content and argumentative practices required for developing scientific conceptual understanding (Hand and Norton-Meier 2011). Meanwhile, the role of language in the science classroom needs much more attention in the field of argument-based inquiry. To us, lack of understanding of the concept that language is an essential learning tool in science (Norris and Phillips 2003) seems to lead to a lack of understanding of the epistemological role played by language. In part, overemphasis on the structure of argument grounded in Toulmin's work dissociates knowledge of argument from the practice of argumentation and science knowledge to be developed. Language involved in argumentation and science content should be learned through living the language and by using the language (Hand et al. 2009).

Although very little research has purposely examined teachers' knowledge bases necessary for implementing immersive approaches to argument-based inquiry (Evagorou and Dillon 2011), it converges to highlight a special body of teacher knowledge for argumentation. This line of research primarily focuses on identifying what constitutes this specialized knowledge and as a result three components are recognized: teachers' understanding of (a) the structure of argument and nature of argumentation, (b) students' conceptions of argumentation, and (c) effective instructional strategies for argumentation (Gray and Kang 2014; McNeill and Knight 2013). However, this view is limited in that it does not engage with teachers' knowledge of language and how it is important for science, knowledge of prosocial environments, and knowledge of conditions for negotiation. The presence and strength of each of these knowledge bases and the coherence between them are critical to the quality of teacher knowledge for argument-based inquiry (Park and Chen 2012). Future research efforts are needed to understand how teachers coordinate and apply different knowledge bases to effectively implement adaptive pedagogy (Cavagnetto 2008).

In addition to epistemological orientations and knowledge bases, much research on teachers in the context of argumentation has focused on pedagogical practices critical to successful implementation of argument-based inquiry. Research reveals that teachers need to promote active dialogical interactions, especially between students, by effectively managing ideas and information generated by students and by modeling engagement in argumentation (Chin and Osborne 2010; Varelas et al. 2008; Wilson et al. 2010). Framing productive questions that probe and challenge students' ideas and reasoning is another important pedagogical practice required for teachers integrating argumentation into science instruction (Cavagnetto 2010; Günel et al. 2012; Windschitl et al. 2012). However, this does not imply that questions are only generated by the teacher. Rather, question generation should be considered as a function of the group—students or the teacher. Teachers also need to provide "just in time" scaffolding for student engagement in authentic argumentative practices such as a structured writing frame, thoughtfully designed discussion board, argumentation tasks, etc. (Choi et al. 2014; Dawson and Venville 2010; Erduran et al. 2004), that is, the scaffolding is provided at the time of need not as a precursor for involvement in the inquiry. More importantly, teachers are required to offer opportunities for negotiation and critique of ideas (questions, claims, evidence) through small group work, whole-class discussion, group presentations, and so on (Cavagnetto 2008, Hand et al. 2009).

Understanding pedagogical practices, coupled with epistemological orientations and knowledge bases required for teachers' effective implementation of argument-based inquiry is a key step to the development of interventions that will improve and ease teachers' use of argumentation. In turn, students' science learning opportunities and outcomes will advance (Duschl et al. 2007; Osborne et al. 2003; Sampson and Blanchard 2012). However, these three aspects are often presented as equivalent in the literature. In the future, there is a need to shift this perspective to highlight that epistemological orientation is the critical factor in how successful teachers will be in creating the learning opportunities for students that such immersive environments present.

Much has been written about the trouble teachers have in moving from professional development workshops to successful implementation of the critical approaches, with teacher concerns focused on such issues as curriculum coverage, shift in pedagogical practices, and management of both classroom environments and content. Very little attention has focused on teachers' epistemological orientations and how these align with their pedagogical content knowledge and instructional practices. In essence there is a need to spend more time on shifting teachers' epistemic orientations in order to promote a change toward an *approach* to teaching, rather than only helping teachers develop strategies for argument-based inquiry approaches.

Missing to date is the focus on the alignment among the three key aspects necessary for teachers to move toward higher-level implementation with immersive argument-based inquiry. Stated differently, each component is often considered independently in both research and teacher professional development programs—but overlooking the significance of the alignment across them. The shift from traditional approaches to immersive argument-based approaches requires changes across a number of dimensions and, more importantly, coordinated alignment among those changes (Cavagnetto 2008). Immersive approaches to argument-based inquiry are not a prescribed curriculum or a set of kit-based activities, but an approach to science curricula that requires teachers to align their orientations, knowledge, and practices for integrating key features of argument-based inquiry into their science lessons. Such alignment occurs through necessary adjustments across the three aspects based on understanding of their students and teaching context. A change in one might not be sufficient to make changes in a teacher's implementation level if the change is not well aligned with changes in the others. Future research should explicate the relationship among the three and mechanisms through which teachers make a strong alignment across them—enough alignment to stimulate successful implementation of an immersive approach.

Conclusions

We began this paper by arguing that too little attention has been paid to working through the nuances that are embedded in some of the language and ideas put forward by science education researchers. The future requires a major transition in how we practice language in the science classroom. The rapid shift in technology and students' engagement with this technology has created even greater differences in how language and inquiry are being used in and out of the science classroom. To be clear, the key part of this rapid evolution is not the technology itself, but rather *how* students engage the various knowledge bases as they use language in their everyday lives. Therefore, our ability as a community to move forward and have broad impact on how science is learned in school classrooms, and to shift students' engagement with science, requires us to pay much more attention to the myriad of knowledge bases and resources both teachers and students bring into the science classroom. Rushing to adopt rhetoric without paying attention to the meaning and application of such rhetoric prevents the in-depth discussions of bridging the gap between where students are: what resources they use and have available to them and how we can access these for improving the learning and teaching of science.

We have argued that the future of inquiry is to develop immersive environments where students see themselves as becoming part of the whole rather than simply being an individual within a cluster of individuals. This requires us to have more nuanced understanding about the role of language and the perspective of argumentation necessary for such environments. It will also require a much more adaptive pedagogy than is currently being advocated. While we believe that this shift is critical for us as a community moving forward, we also believe that as a community we cannot simply only examine outcomes at a micro-level, that is, by relying on case studies. We need to examine impacts at a much broader level to understand all the elements discussed in this paper—and to truly help us impact science classrooms.

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