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Science education as a pathway to teaching language literacy: a critical book review

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Abstract In this paper, I present a critical review of the recent book, *Science Education as a Pathway to Teaching Language Literacy*, edited by Alberto J. Rodriguez. This volume is a timely collection of essays in which the authors bring to attention both the successes and challenges of integrating science instruction with literacy instruction (and vice versa). Although several themes in the book merit further attention, a central unifying issue throughout all of the chapters is the *task of designing instruction which (1) gives students access to the dominant Discourses in science and literacy, (2) builds on students' lived experiences, and (3) connects new material to socially and culturally relevant contexts in both science and literacy instruction—all within the high stakes testing realities of teachers and students in public schools*. In this review, I illustrate how the authors of these essays effectively address this formidable challenge through research that 'ascends to the concrete'. I also discuss where we could build on the work of the authors to integrate literacy and science instruction with the purpose of 'humanizing and democratizing' science education in K-12 classrooms.

Keywords Integrated science and literacy instruction/science instruction for English learners · Democracy and science education · Multicultural science teacher education

Introduction

Having attended the second Institute on Science Education Research [ISER II] in 2007 from which this volume, *Science Education as a Pathway to Teaching Language Literacy*, emerged, I feel privileged to be able to formally engage with the 'final' product that has captured some of ISER's rich discussions on integrating science and literacy education. In her foreword to this volume, Margaret Gallego, citing Davydov (1990), reminds us of the importance of 'ascending to the concrete'. As Gallego points out, the research studies conveyed in this volume effectively balance the theoretical with the practical. Rather than

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requiring us to imagine our own applications of their work for K-12 classrooms, the authors provide us with detailed portraits of 'theory-in-practice'. Each of the authors describes the work they presented at ISER II: To address the challenge of developing students' science and language abilities in ways that are engaging, relevant, and transferrable, James Gee introduces a situated learning matrix concept that mirrors the goal-driven problem spaces created in video games. Alberto Rodriguez and Cathy Zozakiewicz describe results from a professional development intervention to help elementary teachers create and implement technologically-enhanced integrated science and literacy lessons that are culturally responsive. Katherine Richardson Bruna reflects on language play as a linguistic resource of Mexican newcomer students in a Midwestern science classroom. Kimberly Gomez, Jennifer Sherer, Phillip Herman, Louis Gomez, Jolene White Zywica, and Adam Williams describe the effects of literacy scaffolds in science instruction that resulted from the collaborative work of teachers and researchers in high school science classrooms. Tanya Cleveland Solomon, Mary Heitzman van de Kerkhof, and Elizabeth Birr Moje analyze the conundrum of enhancing science text with seductive details that often complicate students' abilities to find the main idea. Finally, David Crowther gives an overview of the research on inquiry instruction for ELLs and provides examples of approaches that have proven effective for developing the science and language abilities of ELL students in K-12 classrooms. The format of this volume honors the richness of the ISER discussions, such that each chapter is followed by a response from another chapter's author(s), which is then followed by a response from the author(s) of the original chapter, thereby adhering to the social constructivist approaches to which the authors ascribe.

Science and language emerging from students' lived experiences

Gee clearly argues for more student-focused reforms to science and literacy education in his essay, *Science, Literacy, and Video Games: Situated Learning*. He begins with a critique of the 'content fetish' approach to science education that still prevails in many science classrooms. That students should be required to memorize a set of key facts from all the major disciplines within the sciences seems impractical as well as impossible, and also relatively ineffective: Teaching the facts does not prepare students to use them in context, nor does it promote long-term retention. Gee also critiques the more popular 'anti-content fetish' proposed by those who believe more attention should be given to the practices and habits of mind of a scientist over teaching scientific facts, or in other words, the apprenticeship model of science education. Gee points out that scientists have a personal investment in their activities, and do science not to learn it, per se, but rather to advance it. Most students do not come into the science classroom with the same type of investment in advancing scientific knowledge. Too often, it is incorrectly assumed that engaging students in inquiry science activities that resemble the practices of professional scientists is *enough* of a hook to interest all students in science learning. Of course, students should become familiar with those practices, but if the majority of students are not going to become scientists, should the focus of science education be on encouraging our students to think and act like scientists, or rather to deeply understand those practices 'as an enterprise—as a "form of life"—a distinctive way of being/doing/valuing with other people' (p. 3)? The latter approach, I would argue, might better prepare future professional scientists and non-scientists alike for democratic engagement with socioscientific issues.

The title of this book, *Science Education as a Pathway to Language Literacy*, indicates that the primary topic of discussion will be the integration of the teaching of science with the teaching of (English) language development. However, as we might expect from these authors, the ideas of language and science literacy are presented in a much more nuanced fashion. In many of the essays, the authors refer to the *multiple literacies* that can be promoted through integrated science and language instruction. Singer (2003) provides us with a useful definition of literacy as 'the ability to participate in a conversation with a level of competence and confidence' which inevitably 'requires both skills and knowledge' (p. 181) within a particular discipline. Multiple literacies, he maintains, are then required, since the knowledge and skills required to competently participate in a conversation will differ according to the content and context of the subject matter (p. 182). Gee reminds us that 'learning is always about learning a "language" (a representational system)' (p. 1). Since we are talking about language and literacy in *science,* then, it seems pertinent to also consider the widely debated concept of scientific literacy. The American Association for the Advancement of Science [AAAS] defines scientific literacy as the required 'understandings and habits of mind that enable citizens to grasp what [scientific] enterprises are up to, to make some sense of how the natural and designed worlds work, to think critically and independently, to recognize and weigh alternative explanations of events and design trade-offs, and to deal sensibly with problems that involve evidence, numbers, patterns, logical arguments, and uncertainties' (AAAS 1993). Gee encourages us to consider how the development of multiple literacies, including scientific literacy, could be fostered in a way that builds on student interests in a technological, web-based, 'ProAm' era. As Gee explains, 'Pro-Ams are people who have, as amateurs, become experts at whatever they have developed a passion for' (p. 21). For Gee, multiple literacies would therefore include developing the technological, digital, and new media skills and expertise, or what is now being commonly referred to as 'new literacies', in the science classroom. Gee encourages educators to reconceptualize science lessons and activities in terms of using the classroom as a 'goal-driven problem space' that draws on the expertise and interests of students in a digital age. A goal-driven problem space is a type of situated learning matrix, which, according to Gee, is created by a unique pedagogy found in most high quality video games. Gee argues that video games (or card games like *Yuh-Gi-Oh* or *Pokemon*), contrary to being thought of as a sort of 'brain drain', require the development of a particularly complex set of skills that users must employ in richly developed problem-solving scenarios. These games provide ideal conditions for authentic learning and *retention*, such that the user's experiences are goal-directed and socially mediated. Content is acquired only as it is necessary for successful participation in a particular game. Content learning is situated, in other words, in relevant contexts. Users are provided with immediate feedback on their learning (maneuvers), from which they can tweak prior knowledge and apply it to new situations: 'As players move through contexts—each containing similar but varied problems—this helps them to interpret and eventually generalize their experiences. They learn to generalize—but always with appropriate customization for specific different contexts—their skills, procedures, principles, and use of information. This essentially solves the dilemma that learning in context can leave learners with knowledge that is too context specific, but that learning out of context leaves learners with knowledge they cannot apply' (p. 9).

Gee affirms that in these goal-driven problem spaces, a social identity is crucial for learning. Learning the content required to participate in a game is dependent on the player's investment in appropriating the social identity required of a player in that particular game (i.e. using Gee's example here–as a SWAT team member in *SWAT4).* Gee reiterates that a social identity requires the establishment or appropriation of a shared set of goals and norms agreed upon by members of a particular social group. Indeed, learning is optimal when individuals have a *vested interest* in appropriating a social identity in order to gain access to particular experiences and opportunities. I learn the rules of the 'game of Academia,' for example, because I have a vested professional interest in participating within the educational research community. This is where I believe that the apprenticeship model in science education has failed. Though its contribution to moving the primary curricular focus in science education from a transmission of facts to the development of scientific habits of mind should not be understated, the apprenticeship model incorrectly assumes that all students have a desire to think and act like (traditional) scientists—or that all scientists think and act alike. [The same could be said for English language learning, for that matter (see Norton Peirce 1995)]. However, just as not all students are going to appropriate scientist identities, nor are they all going to be invested in the simulated realities of video games. It is always necessary to complicate the construct of social identity since, when we agree to appropriate the goals/norms of any community in order to participate in it, we do not leave behind the multiple social identities that we have already constructed (or co-constituted), nor those that have been constructed for us.

Gee's argument that video games provide students with opportunities to engage in complex situated learning matrices which may be useful to develop the multiple literacies requires of a 21st century citizenry is well-taken. Children and adolescents are increasingly becoming involved in gaming, and the use of gaming in instruction has demonstrated learning gains for both male and female students alike (Papastergiou 2009). However, it is imperative that we keep front and center the degree to which science instruction has catered to the interests of male students over female students as well as to Anglo European students over students of color. It is in this regard that the concept of a social identity can get a bit messy. We should be particularly vigilant about the potential gendered/classist/ethnocentric nature of proposed reforms in science curricula.

It should be made clear that Gee is by no means proposing the substitution of science teachers for video games, although it is fair to say that he would probably support the thoughtful integration of gaming in science instruction. However, Gee's main point is to encourage us to think about the implications of gaming pedagogy for the classroom. The challenge he proposes is how to design activities that build on and develop students' capabilities and multiple literacies through the kinds of goal-driven problem spaces created in video games, in order to promote the development of the multiple literacies required for participation with/in the science community and the real world of today's technologically advanced 'Pro-Am' society. What Gee does not provide are specific examples of what these goal-driven problem spaces might look like in a typical science classroom, which would have been very useful, particularly to those of us with little to no gaming experience.

Another key point from this essay was particularly pertinent for me. His work reminds us that students are often quite literate in ways that we grown-ups are ignorant. How many of us have relied on our students to help us with the use of instructional technology in our lessons? Although video games were once written off as an endeavor of the 'less than scholarly', there is now growing evidence that the quality of learning in high quality games far surpasses the cognitive complexity of what is required of students in most classrooms (Gee 2003). And, so, we should be wary of how we continue to refer to the literacy deficiencies of our students and perhaps start to think more about the new literacies that we could use to bridge the 'multiple worlds' within diverse schools, homes, and communities (see Phelan et al. 1993), as well as the virtual worlds of gaming and the Internet.

The question is how to design or implement these problem spaces in a way that has the same pull for *all* students that video games might for *some*. Students choose which video games they want to play–e.g., whether they want to appropriate the identity of a SWAT team member for the duration of a game–*or whether they want to play video games at all*. In science classrooms, we expect all students to participate, regardless of whether we engage their individual interests and unique intellectual resources. The reality is that students are agents and will continue to make choices about their learning.

Richardson Bruna also echoes Gee's call to become familiar with and incorporate students' complex literacy practices in science classrooms. In the science classroom Richardson Bruna describes, Mexican immigrant students use *chistes* (jokes) to play with language, a common literacy practice in many Mexican communities. Citing Briggs (1988), Richardson Bruna explains that 'joking serves as a relatively low-tech, low-stakes means for individuals in a culture that values verbal artistry to demonstrate their competence with language' (p. 65). Having learned most of my Spanish in Mexican fishing communities, I can attest that, whereas the formal schooling of community members was relatively low (primarily due to issues of access), the language play of *chistes* was particularly complex, and something with which I still fumble even after attaining a respectable level of oral proficiency.

Richardson Bruna describes how Mexican newcomer students use culturally-laden oral practices to *bring about* differences in their science classroom. In this study, the students use language play to exert agency and counter the teacher's deprecating (however intentional or unintentional) remarks. They do so, Richardson Bruna proposes, not to disrupt learning, but rather to make room for learning to occur. This is an important distinction. Richardson Bruna refers to the students' use of language, then, not as *collision moments*, but as *collusion moments,* or the 'collective use of play to achieve some (usually unsanctioned) end' (p. 62). Students use language play to overcome the demoralization bestowed upon them by a teacher who contextualizes a fetal pig dissection activity as one that should interest students as sons and daughters of meatpackers. In one example, a student refers to the activity as 'la passion del puerco,' and another student jokes about using the fetal pig heads to make pozole. Through language play, students also resist what they view as an unethical practice of wasting a pig and exert agency while being asked to participate in an 'educational activity' that they clearly find repulsive. Chistes enable students to make room for their learning through *collusion moments*, rather than to opt out of it.

Both Richardson Bruna and Gee, remind us that, while we help our students attain fluency in English and the academic language of science, we must do so in ways which build upon students' own complex language practices: 'the failure of schools to engage students in general and culturally- and linguistically non-dominant youth in particular can be understood as a failure not to provide students with opportunities to take on projective identities in various communities of social practice, to reveal to students a multiplicity of power potentials' (Richardson Bruna, p. 64). Culturally relevant teaching is not only about connecting curricula to students' *brought along* social and cultural differences (cultural responsiveness), but also making room for students to *bring about* differences in science instruction (social justice/agency/power). Instead of ignoring the students' language play, the teacher could collaborate with students to create a third space in the science classroom (see Barton and Tan 2009), taking advantage of *collusion moments* to facilitate science and language learning on the part of both students and the teacher. The challenge in this, however, is to prepare teachers who are capable of incorporating cultural and linguistic practices of students in the science classroom to help students connect science and personal worlds. Herein lies complexity of 'ascending to the concrete' in this particular case: The teacher in this classroom was assigned to teach the newcomer students because, having learned basic Spanish as a missionary in Latin America, she was considered the most capable faculty member at the school. In fact, I wondered whether her effort to frame the dissection activity as meaningful to the students whose families work in the meatpacking plant was a misguided attempt at culturally relevant instruction. This study highlights the urgent need for ongoing professional development and teacher education that promote *culturally responsible* teaching in science classrooms (see Zozakiewicz 2010).

Addressing issues of cultural relevance, access and accountability through responsive professional development

Rodriguez and Zozakiewicz describe an intervention study which prepares elementary school teachers to teach culturally relevant science lessons that integrate technology, English language arts, and English language development. Given the unfortunate political context of *No Child Left Behind* in the United States and other similar legislative mandates abroad, many elementary school teachers feel they have had to sacrifice science instruction for math and literacy instruction. In making more transparent for the teachers the connections between science and literacy, Rodriguez and Zozakiewicz establish greater buy-in. Lessons developed incorporate activities that promote multiple literacies in both the genres of science and English language and literacy. For example, students practice using narrative skills to complete a story starter about a drop of water that started out in a small pool and gets transported by ‘Mr. Big Foot’, which then goes on to phase through various stages of the water cycle. Every lesson also has a multicultural/sociotransformative constructivist (sTc) component. The sTc framework integrates social constructivism as a theory of learning with multicultural education as a theory of social justice (see Rodriguez 1998, for a detailed explanation of the sTc framework). Instructional activities designed within this framework engage students in hands-on/minds-on activities that are ‘critically engaging and intellectually meaningful’ as well as culturally responsive (see Rodriguez 1998, p. 590). For example, students, as teams of NASA scientists and engineers, design a rover that would explore a solar body they select and include elements of their own cultural backgrounds in the rover design. They also create a digital quilt to represent the accomplishments of women in space, and reflect on the history of gender discrimination in space exploration. In addition, each activity promotes the development of technological literacy. Students were able to take ownership over their learning, and to create and manipulate knowledge using learning technologies such as Quicktime movies, Inspiration software, etc., as well as use technological tools in science such as Vernier probes.

Gomez, et al., also provide an example of a professional development intervention study that aims to improve reading, writing, and academic language skills of lower achieving students in urban high school science classrooms. Researchers and teachers work together in this study to integrate literacy tools that scaffold reading comprehension. Double entry journals, for example, ‘provide a structure for students to monitor and document their understanding of science texts’ and help students ‘read and reflect on what they have read’. These tools help teachers ‘focus student reading on an important idea or skill unique to that particular text (vocabulary, main ideas with supporting ideas, etc.)’ (p. 99). Literacy tools are integrated, in this case, in an environmental science curriculum that is socially relevant. Lessons are socially and culturally contextualized as case-based inquiry investigations into real world issues. For example, the students’ final project is to propose a new environmentally sustainable location for a Florida school. Students engage with texts that support the inquiry versus texts that merely introduce content, so that they learn and apply vocabulary *in context*, which is proving to be more effective in science instruction than frontloading academic vocabulary (see Wallstrum and Crowther 2010). Students also develop authentic science literacy skills, for example, using computational tools to make charts and tables and participate in evidence-based decision-making.

In this study, 'literacy work is always *in support of* the science learning' (p. 104), a contrast to Rodriguez and Zozakiewicz's approach which seems more focused on embedding science lessons in literacy instruction. This difference reflects the responsiveness of both research teams to the needs of the teachers' institutional and political contexts. Whereas high school science teachers are largely much more focused on student understanding of science content, elementary school teachers are more concerned with students' literacy and language skills. Gomez, et al., point out that science teachers have not been well-prepared to use texts in science (see also Solomon, et al., in this volume), while Rodriguez and Zozakiewicz stress how elementary teachers have been compelled in the current political context to forego science teaching for literacy instruction. Improvements in students' literacy skills and science achievement resulted from both studies. The value of these results as catalysts for encouraging the integration of literacy and science instruction in both primary and secondary schools should not be understated.

Gomez and colleagues found that teachers, after the first year of intervention, were still viewing the literacy activities as distinct 'add-ons' to the science curriculum, rather than as tools to improve both literacy and science achievement. However, as a result of this response, the researchers redesigned their intervention to make the synergistic connections between literacy and science more transparent to the teachers. By the end of year 2, teachers were more actively modifying the literacy tools and integrating them into their instruction. Gomez, et al., also found ways to win the coverage battle. While the integration of literacy tools slowed down the pace of instruction, both teachers and students found the trade-off in increased science content understandings worthwhile enough to slow down coverage. Therefore, the researchers succeeded in implementing reforms that worked *within* rather than *against* the political context of teacher work. I am confident there would be great interest in experimenting with the implementation of these literacy tools in elementary and middle school classrooms where teachers are more focused on teaching students to read. The tools described help make more transparent the synergistic connections between (read/write) literacy and science learning and would surely be welcomed in elementary schools where there is often a need to 'justify' science teaching.

Rodriguez and Zozakiewicz similarly found that some teachers in their study were implementing the intervention to a greater degree than others, despite the fact that all participating teachers had been selected for their espoused commitments to the project goals. This proved to be very frustrating for the researchers. As these challenges arose, they developed strategies to overcome them. Some of the strategies that Rodriguez and Zozakiewicz found to be most successful were *students as change agents* (see Rodriguez et al. 2008), *prompted praxis* (see Rodriguez et al. 2005) and *modeling and demonstrating*, the latter being the focus of their chapter in this volume, which included several action components: collaborative planning, summer institutes, on-site support, team teaching, and monthly meetings. Each of these components proved to be effective in modifying the teachers' practice. Researchers 'worked closely with teachers in multiple contexts to illustrate how science practices could include the teaching of multiple literacies, using learning technologies, while still meeting the state science content standards' (p. 31).

In both interventions, the instructional approaches described could easily be implemented in other settings. The researchers in these two professional development intervention studies, 'ascending to the concrete', do not seek to merely describe a problem but work in collaboration to troubleshoot solutions. Teachers would also find these chapters accessible and useful; the authors in these chapters, therefore, both ascend and extend to the concrete.

Access to the dominant discourses in science and literacy

Solomon and colleagues address the conflict brought about by enhancing text with relevant and engaging details that may distract students from understanding the main idea. This chapter, like that of Gomez, et al., encourages us to think about the complex task of designing socially and culturally responsive reading materials that still give marginalized students access to the language of power. The two goals are by no means mutually exclusive, but areas of conflict are certainly present as the authors in this study point out. Identifying the main idea is an important skill not only for success on standardized tests, but also for engaging with socially relevant issues in science and other disciplines. Underserved students often struggle with identifying the main idea in informational text. As illustrated in this study, the main idea they identify frequently corresponds with what most interests them. The authors discuss the degree to which seductive details designed to hook students into reading a science text can thus distract them from attaining the (teacher or text-intended) learning objective. On the other hand, they show that eliminating those details entirely can also cause comprehension problems. Solomon and colleagues urge text writers to think carefully about the types of seductive details they include that might distract students. The researchers, however, also maintain that since it is nearly impossible to determine a priori what details might confuse students, the task of sorting out seductive details is largely left to the teacher as mediator of the text.

Rodriguez and Zozakiewicz, in their response to this article, encourage the authors to reflect on the manner in which students are being asked to describe the main idea. They propose that perhaps it is the question itself that needs to be the focus of improvement. For example, Rodriguez and Zozakiewicz propose that students be asked to identify the author's main idea rather than to identify the main idea in general. Solomon and colleagues, in their follow-up response, report that although they used a variety of approaches and questions to elicit from students the author's main idea, they still found that students had difficulty with this task, generally reporting the main idea as whatever facts were most engaging to them. In my own experiences as a teacher and researcher, I have also found difficulty trying to get students to elicit the main idea from a text, even when asking for the author's main idea, since students often then 'become' the author in a sympathetic fashion, imagining that the author would share the student's interests. However, I believe that what Rodriguez and Zozakiewicz propose, consistent with the *metacognition* aspect of the sTc framework (Rodriguez 1998), goes beyond reframing the question's wording to include 'the author's main idea', but rather assisting students to develop metacognitive skills around the Bahktinian question of who is doing the talking. Students should be encouraged to reflect more deeply, in other words, on the author's interests and investments, and to think more carefully about what is it that the authors would want their readers to know (and to believe). I would also add that, consistent with the *reflexivity* component of sTc, students should be encouraged to reflect on how the author's investments might conflict or correspond to their own beliefs and experiences.

The work of Solomon and colleagues lends itself well to this type of metacognitive activity. They propose that teachers use seductive details as launch pads for further inquiry and reflection. Texts should not only be a part of inquiry activities but should also be a source of inquiry themselves. They affirm that the voice of the teacher and/or single text should not be the only one in the classroom—teachers should use multiple and even conflicting texts to encourage students to find and reflect on the main ideas of a variety of texts around the same topic. In this way, students can discover for themselves how information can be embedded in different contexts, conveyed through diverse voices, and relayed with conflicting intentions. This type of critical investigation also meets the dual goals of assisting students in identifying the main idea as determined by the author or teacher, but also helping them to develop critical literacy skills they can use to disrupt the power differential inherent in author/teacher (knower) versus student (learner).

David Crowther reiterates the need for teachers to develop an awareness of their students' cultural and linguistic backgrounds, particularly given the increasingly diverse student population in K-12 classrooms. In his chapter, he focuses specifically on the need for attention to issues of language development in science education. He embeds his discussion in issues of equity and access: Science education is being denied students based on their English Language Learner status. Students who are English learners have been systematically excluded from rigorous science instruction due to the misguided belief that English proficiency is a prerequisite for science learning in English-dominant schools. His chapter gives an overview of the research that contradicts this commonly held belief and shows that English language development and science learning are complementary activities. What is notable about his overview of strategies for integrating language development and inquiry science instruction with students who are English Language Learners is its accessibility to classroom teachers. In his chapter, he 'ascends to the concrete' by describing strategies that teachers can implement to address both science and language standards. Crowther highlights results from several studies that illustrate how gains in science understandings, language development, and literacy skills increase when ELL students engage in inquiry science lessons. He urges that research and strategies for teaching inquiry science to ELLs become a key component of teacher education programs.

One of Crowther's most significant contributions to the research on inquiry science education for ELLs is his work related to the nature of vocabulary instruction in inquiry science. He and his colleagues have shown that embedded vocabulary instruction may be more effective in improving vocabulary learning in science than the frontloading approach that has typically been recommended for vocabulary instruction with English language learners (Wallstrum and Crowther 2010). Although he does not discuss this work in depth in the chapter included in this book, it speaks to the work of other authors in this volume. Gomez, et al., in particular, describe how vocabulary instruction is not taught through discrete direct instruction activities, but rather that 'students identify (through annotation) the vocabulary word in context, use double-entry journaling and/or discussion to consider the role of the vocabulary word with respect to the larger science concept(s) under study, and to demonstrate use of the vocabulary word through summary writing, extended responses or end-of-lesson question responses' (p. 119). This is an area of research that has not yet been thoroughly studied, and I look forward to Crowther's future work in this area as we continue to investigate best practices for integrating language development and science instruction.

'Humanizing' and 'democratizing' science and literacy education

If we are to adhere to social constructivist and sociocultural approaches to literacy, language, and science education, as these researchers clearly do, we must also consider the larger sociopolitical context within which our educational system is situated. In this volume, Katherine Richardson Bruna calls for 'a model [of science education] that not only theorizes science "play" through a process of interrogation and generalization of science-learning experience, but one that humanizes and democratizes it as well' (p. 17). Richardson Bruna asks, 'When simulated in a classroom environment, how could the talk and activity of a real science domain in some way prepare students for democratic life?' Although teaching for democracy has become a common rhetoric in social studies education, it is an issue that has yet to be fully explored in science education. It is a topic, however, that should not be isolated to the humanities. When we discuss issues of language and literacy in any subject, we must consider how we are teaching students to both read the world and the word. How can science, literacy, and language instruction prepare students for democratic engagement? What characteristics of science 'talk and activity' are also characteristics of the 'talk and activity' of civic participation?

The many parallels between democratic education and science education are apparent in the chapters that are included in this book. Equally fundamental to democratic education is the development of students' capacities to engage in informed debate around issues that affect their local, national, and global communities. Unfortunately, opportunities for students to participate in the type of debate that is common in science and in the democratic political sphere are few and far between in science classrooms (Osborne 2010). Additionally, both science and democracy require collaboration and knowledge-sharing among community members. In effective integrated science and language literacy instruction, students collaborate, engage in science talk, and use scientific reasoning in inquiry-based investigations that build on students' individual and sociocultural experiences and are tied to local physical and ecological environments (Stoddart et al. 2010).

Rodriguez (1998), in his sociotransformative constructivist framework, talks about the need for improving students' metacognitive abilities so that they develop awareness and agency with regard to what and how they learn. Although agency is the focus of the edited book that came out of the first ISER and therefore not the main focus of this volume (see Rodriguez et al. 2008), a crucial aspect of facilitating students' literacies in language and science is the way in which we encourage them to be agents for their learning and to use their voices to effect change. Key to democratic education is fostering the ability to speak one's mind, to be able to consider '(a) who should have authority to make decisions about education, and (b) what the moral boundaries of that authority are' (Gutmann 1987, p. 11). In this volume, student voice was included in nearly all of the studies, to one extent or another. For example, students were reframed as agents for their learning through collusion moments rather than as disruptive problem children resistant to learning. Students were encouraged to effect educational reforms in the classroom, pressuring teachers to implement technology integrated lessons that would improve student learning. The inclusion of student voice was evident as well in research methods and data collection: Focus groups with students were conducted to elicit feedback on instructional reforms and students were surveyed to rate the usefulness of various implementations. Students were encouraged to reflect on the reasons why they were being asked to learn, for example, how to write an annotated bibliography. Encouraging students to develop and use their voices to effect changes in their own learning is one element of how we can integrate principles of democratic education in both science education research and instruction. Although democratic education cannot occur without fostering student agency, this element alone does not answer the question of how to democratize and humanize science education as a regular practice in science classrooms.

The authors in this volume discuss the topic of how to build on students' lived experiences and provide students with the science, language, and literacy tools they will need for interplay with dominant Discourses in science and literacy but do not fully explore how students could then be encouraged to use those Discourses to critically and authentically engage with citizen science and socioscientific issues, or to reflect upon what is means to do responsible science.

Rodriguez and Zozakiewicz democratize and humanize science when they facilitate among students and teachers a discussion of the historical marginalization of women and minorities in aerospace sciences. A next step toward promoting critical democratic literacy in science could be to investigate, for example, the ethical consequences of space exploration, such as the growing amount of synthetic debris in space. Solomon, et al. encourage teachers to use multiple, even conflicting texts, in the science classroom so that the teacher or science textbook are not the sole voice of scientific authority. In the name of democratizing science, this piece represents an ideal building block for encouraging students to reflect the nature of bias and funding in scientific research and more carefully evaluate claims of objectivity. Gee's work with youth literacies in gaming is a clear demonstration of how technologically and critically literate students can become in the information age. If we are preparing students for democratic activism in the age of new media, we must build on their new media literacies to effect change, to promote participation and transformative action in science, to encourage students to reimagine the role of a scientist. Gomez, et al. provide students with a 'democratized' application of the science content and literacy skills they learn through the task of identifying a sustainable location for a Florida school. A step toward further democratizing this activity would be to encourage students to use their knowledge for transformative action by engaging them in actual local socioscientific projects. By assisting students to transfer the skills from a simulation in which they identify the most sustainable location for a Florida school to real-world democratic action in local communities, we familiarize them not only with the science content and literacy skills they need to access the dominant Discourses but also provide them with the tools they can use to effect change (e.g., Roth and Lee 2004).

One of the primary barriers to the integration of critical literacy and democratic action in science and literacy instruction is the political context in which teachers are currently embedded. While classroom teachers are increasingly discouraged and even punished for going against the grain in this era of accountability, researchers hold the more privileged position of being able to do so. We should take advantage of this privileged status wherever possible, particularly if our goals as researchers include improving the status and participation of marginalized individuals in the sciences. Attention to critical perspectives in science and literacy integration can help us reimagine science instruction for the education of scientifically literate citizens who both participate in ethical scientific practices as well as hold science accountable in its honored status as a practice of improving society. We must work to pursue a 'science for all' that reflects a true commitment to participatory democracy and rejects the commodification of underrepresented individuals in science as pawns for increased global competition, but instead offers opportunities for all students to engage in scientific practices that more ethically serve the interests of local and global communities.

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