The University of Texas at Austin
Texas Education Review
College of Education

Journal Homepage: Texas Education Review

Published online: July 2019

Submit your article to this journal

Using Literacy to Enact Critical Pedagogy and Scientific Inquiry: An Analytic Literature Review

ANNE DALY-LESCH
The University of Texas at Austin

To cite this article: Daly-Lesch, A. (2019). Using literacy to enact critical pedagogy and scientific inquiry: An analytic literature review. *Texas Education Review*, *7*(2), 45-59.
http://dx.doi.org/10.26153/tsw/2284

Using Literacy to Enact Critical Pedagogy and Scientific Inquiry: An Analytic Literature Review

ANNE DALY-LESCH
The University of Texas at Austin

Students who enter K-12 classrooms are active meaning-makers and inquirers and come to school eager to explore their physical, social, and cultural worlds. Literacy is a powerful tool that can be used across content areas to generate new understandings, develop skills, and interrogate curricular knowledge (Janks, 2010; Moje, 2015; Smith, 1934). This is especially true within the domain of science education where students are engaged in reading texts, designing investigations, and crafting scientific arguments (Cervetti, Jaynes, & Hiebert, 2009; Cervetti, Pearson, Barber, Hiebert, & Bernardo, 2007; Schwarz, Passmore, & Reiser, 2017).

Unfortunately, opportunities to integrate reading and writing into the study of science are rare (Gavelek, Raphael, Biondo, & Wang, 2000). In the era of accountability reform, students spend more time acquiring the technical aspects of reading and writing skills instead of using them to generate new understandings within science (Cervetti et al., 2009). Moreover, students from linguistically, racially, and economically diverse backgrounds experience far fewer opportunities to engage in science-literacy learning due to test-centric curricula and high-stakes testing demands (Davis & Willson, 2015; Nichols & Berliner, 2008; Wright & Gotwals, 2017). Literacy learning that prioritizes the acquisition of skills over using literacy to develop new understandings perpetuates oppressive schooling conditions that contradict the ways people jointly use literacy and science to make sense of the world around them (Hoffman, 2017; Moje et al., 2004; Schwarz et al., 2017).

One way educators have disrupted single-subject learning to integrate literacy with science is through inquiry-based teaching methods. Defined broadly, inquiry is a pedagogical approach that centers all learning experiences around students' curiosities and interests (Maloch & Horsey, 2013; Owens, Hester, & Teale, 2002; Wells, 1999). Within an inquiry-based science curriculum, reading and writing become essential tools to engage in the specific practices of inquiry, such as designing investigations, evaluating multiple sources of information, and developing evidence-based arguments (Schwarz et al., 2016). Pearson, Moje, and Greenleaf (2010) noted the mutual benefits of an integrated science-literacy inquiry approach, explaining that "When literacy activities are driven by inquiry, students simultaneously learn how to read and write science texts and to do science" (p. 459-460). Previous research has examined the effects of an inquiry-based approach in teaching science and literacy, noting the positive impact it has on students' academic learning (Cervetti, Barber, Dorph, Pearson, & Goldschmidt, 2012; Ødegaard, Haug, Mork, & Sørvik, 2014; Pearson et al., 2010), engagement (Cambria & Guthrie, 2010; Guthrie, Anderson, Alao, & Rinehart, 1999), and identity development as readers, writers, and scientists (Håland, 2017; Pappas, Varelas, Barry, & Rife, 2002; Tucker-Raymond, Varelas, & Pappas, 2013; Varelas & Pappas, 2006).

While promising, few studies have examined how an inquiry-based integrated science-literacy approach can be used in the service of critical pedagogy. Critical pedagogy is a broad project aimed at interrogating the ways dominant groups maintain power through the institution of school. Although obscured as objective or neutral, all forms of teaching and learning are governed by ideological beliefs that privilege particular people and ideas as more knowledgeable than others (DeMarrais & LeCompte, 1995). Without interruption, standard forms of curriculum and instruction in U.S. schools privilege White, monolingual English, middle class cultural norms and marginalize the cultural, linguistic, and literacy practices of diverse student learners. The aims of critical pedagogy are to illuminate constructs that serve the interests of the dominant group, interrupt their reproduction

in school, and take action to change them (Darder, 2012; Giroux & Simon, 1988; Luke, 2019; McLaren, 1994).

Critical literacy is situated within critical pedagogy as an approach to using literacy to recognize oppressive ideologies, discourses, and practices in order to enact social change. Critical literacy is often connected to the work of Freire (1970), who believed literacy education could be used to "confront a culture of domination" (p. 54) and situated literacy pedagogy squarely within the social, cultural, and political worlds. Literacy is conceptualized as an ongoing engagement with the "word and the world" (Freire & Macedo, 1987), which requires individuals to "analyze, critique, and transform social, cultural, and political texts and contexts" (Luke, 2019, p. 354). Looking at literacy with this specific lens allows teachers and students to engage with the word and the world to confront injustice and work towards social change.

This review examines literature across integrated science-literacy learning, inquiry-based instruction, critical pedagogy, and critical literacy. By reviewing a specific body of literature related to these areas, I aimed to understand how an inquiry-based approach to science-literacy learning could function to support students' critical investigations into the social, political, and environmental worlds around them. Reviewing recent educational research, I asked: How does literacy facilitate critical inquiry into the discipline of science in K-12 classrooms?

Background

Inquiry-based instructional models are often associated with scholars from the progressive education movement (Duke, 2016). Writing in the mid-1930s, Dewey (1938) proposed a theory of inquiry in which students' experiences and interests served as the foundation for all teaching and learning. Dewey, along with other progressive educators of the time (e.g., Kilpatrick, 1921), believed that engaging students in authentic tasks would lead to high levels of learning across content areas. Similarly, literacy scholars argued that experiential learning created reasons to read and write (Smith, 1934; Whipple, 1925). Smith (1934) argued for an "experience method" of instruction where reading was "used as a tool to further the interests and activities of the children" (p. 218). Progressive educators proposed an alternative vision for education that centered the curriculum and instruction around students' inquiries, interests, and experiential learning.

Decades later, Freire (1970) also proposed a pedagogical vision that centered students' interests and experiences in the curriculum. Unlike progressive educators, however, Freire believed that dominant structures, systems, and ideologies were to blame for the kinds of decontextualized or "banking" (p. 53) forms of instruction common in school. Ongoing cycles of reflection and action were processes used to develop students' consciousness of oppression and engage in political action that would lead to change. For Freire, inquiry was necessary to develop new understandings that could lead to liberation, as he believed that "knowledge emerges only through invention and reinvention, through the restless, impatient, continuing, hopeful inquiry human beings pursue in the world, with the world, and with each other." (1970, p. 53). Inquiry, as both a pedagogical process and way of being in the world, connected teachers and students together in a struggle for liberation, justice, and equity. Although inquiry-based instructional models are often associated with educators from the progressive movement at the turn of the century, Freire's theory of critical literacy is equally important in understanding how inquiry-based instructional methods serve both student-centered and critical pedagogical purposes.

Defining Critical Inquiry

In this review, I use the phrase critical inquiry to capture pedagogical practices that center students' interests and experiences in the curriculum as a means to critique unjust power structures. Drawing on theories of critical pedagogy (Darder, 2012; Giroux & Simon, 1988; McLaren, 1994), critical literacy (Freire, 1970; Freire & Macedo, 1987; Luke, 2019), and sociocultural views of learning (Vygotsky, 1978), I define critical inquiry as a set of critical literacy practices used within classroom learning communities to engage with the sociocultural, political, and natural world. In this review, I specifically examine applications of critical inquiry within the discipline of science in K-12 contexts. The term "critical" signals pedagogical practices aimed at confronting oppressive and inequitable structures, ideologies, and discourses to realize greater equity and justice.

Method

The reviewed articles were selected and examined using a three-part process. In the first phase of article identification, I systematically searched for peer-reviewed articles related to the topic of critical scientific inquiry, limiting the search to studies published between 2000-2018 to examine contemporary instructional practices. I used key terms such as "science," "inquiry," "critical theory," and "social justice" on the databases Academic Search Complete and Education Source. I combined search terms in six different iterations to generate a total of 331 empirical and conceptual pieces related to the topic of this review. I also used bibliographic branching or the snowball technique (Ridley, 2008) to identify 10 additional studies referenced in two studies identified in the first search stage (Brown, 2017; Buxton, 2006).

Next, I began the second phase of article selection by applying a set of selection criteria. Because my focus was on critical inquiry in K-12 science classroom contexts, I first examined studies that explicitly mentioned "inquiry" as an instructional method in the title or abstract of the article (e.g., Buxton, 2006; O'Hallaron, Palincsar, & Schleppegrell, 2015). Within this large set of studies, I discovered theoretical differences between how the authors and I conceptualized critical inquiry. For example, rather than using inquiry as an instructional means to focus on students' interests and disrupt the status quo of classroom instruction, studies like Tong et al. (2014) used inquiry to support students' acquisition of pre-determined canonical science standards. These theoretical differences eliminated the largest number of studies from the broad search. In addition, I excluded ten articles that were not empirical and an additional small set of studies that examined critical inquiry outside of K-12 classroom learning contexts. It is important to note that three studies (Brown & Crippen, 2017; Laughter & Adams, 2012; Wilson-Lopez, Strong, & Sias, 2017) did not explicitly used the term inquiry, but described instructional practices that reflected this teaching method and were, therefore, included. After sifting through the original set of 331 studies using this selection criteria, I identified 11 studies to examine for the purposes of this review.

Once I identified these studies, I compiled a chart to organize aspects of the research process such as the theoretical perspectives, methods, and findings for each study. Using this chart, I identified themes relevant to the question of how critical inquiry was enacted in science content areas. As I developed themes, I reorganized the chart to categorize studies across emergent findings. This analysis, re-reading of the texts, and revision of salient themes produced three main findings, which I discuss further in the subsequent sections.

Findings

Across the studies I examined, three themes emerged that illuminated how literacy instructional practices could support critical scientific inquiry. First, students' interests drove science learning and pursuing those interests through critical inquiry created space to honor their "funds of knowledge" (Moll, Amanti, Neff, & Gonzalez, 1992). Second, critical inquiry invited students to challenge the official science curriculum, critique authoritative texts, and question who held expertise in the discipline. Finally, critical inquiry grounded learning in specific contexts that were ecologically and socially meaningful for students.

Centering Students' Interests and Sociocultural Knowledge

Similar to previous research on inquiry teaching, students' interests drove the teaching and learning experiences for students engaged in critical inquiry practices. In nine of the 11 studies, students were responsible for shaping the kinds of science learning experiences that unfolded in the classroom. For example, Owens et al. (2002) described how elementary and middle school students developed questions that were relevant to their lives, which launched their research investigations into various science topics. However, critical inquiry practices seemed to offer new, distinct advantages to students, namely that when students inquired into topics critically their sociocultural knowledge was a valued resource in developing scientific understandings. As educators continue to seek ways to honor and sustain students' cultural, language, and literacy practices in school (Paris, 2012), these studies shed light on how students can be recognized as powerful scientists, meaning-makers, and inquirers. Below I detail how this occurred in classrooms and also illuminate the tensions that emerged when typical power dynamics between teachers and students were disrupted in the design and implementation of critical inquiry.

Attending to students' sociocultural knowledge. Although culturally relevant pedagogies (CRP) that honor students' cultural backgrounds and experiences (Ladson-Billings, 1995) and inquiry-based science methods are promoted as best practices within critical educational research, the simultaneous enactment of both is rare (Brown, 2017). However, in studies examining critical inquiry practices, students' sociocultural knowledge was viewed as an asset that could further develop scientific understandings. For example, Brown and Crippen (2017) examined ways in which six secondary science teachers used CRP to connect students' home lives with science content learning. They found that teachers planned life science lessons that incorporated students' cultural traditions and practices, such as examining the effects of glucose using students' self-reported food preferences. While the authors explained that this kind of "microlevel culturally responsive knowledge" (p. 126) attended to students' cultural heritage, these practices did not extend to validating students' cultural knowledge in the curriculum.

Buxton (2006) also examined ways that teachers enacted scientific inquiry units that were culturally and socially relevant to students. However, in this study, teachers attended to students' specific critical inquiries in the moment they occurred, demonstrating a value for students' experiences that surpassed their own plans for teaching. In one lesson, preservice teachers planned an inquiry on the different types of fish local to the students' Louisiana coastal community. During this lesson, however, students articulated questions and concerns about water contamination, realizing that many of their families ate fish from these water sources. The teachers changed their teaching plans to follow the students' lead, validating both their concerns and outside-of-school experiences as important in the science curriculum.

In a much different study, sixth-grade students, who identified as members of African American and Latinx immigrant communities, intentionally partnered with their teacher to design scien-

tific inquiry units that attended to their cultural knowledge, expertise, and ways of being (Barton & Tan, 2009). In one unit, students shared their family food and cooking traditions, using this information to inquire into the kinds of plant species used as common food sources in their communities. Through shared inquiry into each other's familial practices, students connected their dietary traditions with family stories through oral history. As students shared family traditions, histories, and recipes, they noted the wealth of resources, knowledge, and diversity within the class. One student, Cindy, used this observation to critique dominant and oppressive discourses that group all "minorities" homogeneously (p. 57). For these students, cultural experiences were viewed as an asset to the science curriculum and a necessary component to investigate the scientific relevance of familiar plant species. These student-centered and culturally-centered inquiries also created space in the official school curriculum to address critical issues like stereotyping racially and ethnically diverse individuals.

These examples showed varying levels of attention to students' interests and sociocultural knowledge while simultaneously practicing critical scientific inquiry. While this is promising, scholars like Babaci-Wilhite (2017) have proposed that more research is needed to understand the effects of including students' home languages in the science inquiry curriculum. Increasingly, students come to school with a range of linguistic practices but are required to conform to English-only curricular demands (Makalela, 2018). Including students' home languages in scientific inquiry offers potential sites to support critical scientific inquiry and learning, as well as provide a means to deconstruct dominant scientific paradigms that may neglect indigenous or non-Western epistemologies in teaching and learning science in school.

Facing challenges in student-led critical inquiries. At times, centering students' interests and sociocultural knowledge in the science curriculum presented challenges for teachers due to time constraints and high-stakes testing pressures. In the two cases in which teachers collaborated with students to develop and enact critical inquiry, structural constraints and curricular mandates became sources of tension. For example, Barton and Tan (2009) noted that despite a successful creation and enactment of a critical inquiry unit, the teacher felt overwhelmed and unable to continue teaching in this way due to time constraints. For the teachers in Buxton's (2006) study who faced significant pressures to raise test scores at their elementary school, curricular mandates created roadblocks to designing a curriculum around students' interests and critical concerns. In one instance, the class abandoned an outside garden project after the school administration reprimanded teachers for straying too far from the curriculum that aligned to high-stakes assessments. Although students across these studies pursued issues related to science and social curricular content, these challenges highlighted the institutional constraints that make such instructional endeavors difficult.

Disrupting Notions of Authority and Expertise

Several studies highlighted ways that critical inquiry was used to address power. Through critical inquiry, students examined the canon of authoritative science texts from a critical perspective to question the expert/novice binaries. The theoretical perspective of critical literacy was developed with the purpose of serving as a tool to "confront a culture of domination" (Freire, 1970, p. 54). Across these studies, it is evident that critical inquiry supported these broad aims by serving as a tool to foster critical consciousness and resist the status quo. For the purposes of this review, I examine closely how critical literacy and inquiry practices were used to challenge traditional forms of science content and authored texts.

Content. Often science discourse is viewed as fixed and authoritative (Bazzul & Sykes, 2011). In school, science content can be constructed as a set of unquestioned facts students must learn (Osborne, 2010). For high school students in Wilson-Lopez et al.'s (2017) study, however, the

engineering curriculum served as a place to both engage "with and against the discipline" (p. 243). Student participants, who self-identified as Latinx and children of immigrant parents, critically read case reports, as well as physically engineered structures and designs. Students used the science curriculum and critical inquiry practices to analyze the ways in which engineered products had material consequences for the designers and those who used the engineered products. The way students read and interpreted engineered designs uniquely positioned them as active, rather than passive, consumers of scientific content knowledge.

In one particular unit in the same study, students inquired into the lack of cultural and socioeconomic diversity among the design team of a company that designed a holographic computer. Armed with this information, the students used what they knew about engineering principles to propose "counter designs" (Wilson-Lopez, et al., 2017, p. 241), which accounted for things like more thorough testing measures to ensure safe use for children and recycling procedures to dispose of materials using environmental stewardship practices. Critical inquiry served as a means to not only disrupt traditional forms of science content taught at school but supported students in imagining new and more socially-just futures through engineering and product design.

This study was one of the few in the review that supported students' action and activism for change. Wilson-Lopez et al. (2017) argued that critical inquiry into engineered designs invited the students in their study to conceptualize discipline-specific instructional practices in new ways, explaining:

> Through enacting both disciplinary literacy and critical literacy in K-16 engineering courses, students can be prepared to perform either as engineers or as active stakeholders, while at the same time moving toward changes that promote more equitable outcomes for all. (p. 244)

For these students, critical inquiry in engineering provided a path to use, as well as resist and disrupt, fixed content standards.

Texts. Critical literacy practices have been explored extensively in English language arts content areas (Janks, 2010; Vasquez, 2004), however three studies in this review extended these literacy practices into the discipline of science. Across each of these studies, students were invited to practice critical literacy by exploring texts through their own inquiry questions about whose knowledge and voice was promoted with authority in the text. O'Hallaron, Palincsar, and Schleppegrell (2015) examined the ways in which 23 elementary-aged learners inquired into the attitudes of authors who wrote their science texts. They examined the language practices of text authors to study how writers created authoritative tones in their compositions. O'Hallaron et al. (2015) argued that a critical reading of scientific informational texts was a way to democratize the curricular space and invite greater participation from students. Given the ways in which students are often excluded from full democratic participation in school due to test-centric curriculum and instructional practices (Au, 2008; Davis & Vehabovic, 2017), critical reading of scientific texts can foster more inclusive learning spaces.

Laughter and Adams (2012) were similarly concerned with the ways in which scientific texts were presented as authoritative. This researcher and teacher-researcher collaborated to invite students to examine individual, societal, and disciplinary biases embedded within science texts typically used in the curriculum. The authors grounded their rationale for critical inquiries in science as a way to increase student participation in the discipline, and as a way to raise students' critical consciousness to respond to pressing social justice issues, such as racial discrimination. Together, sixth grade students and their teacher read Space Traders (Bell, 1992), a text that uses a science fiction parable to examine racism in the United States. After this whole-class reading and discussion, the class engaged in a close and critical reading of the science curriculum to identify biases embedded in the science curriculum. Studies like these highlight the utility of using literacy to foster authentic, discipline-

specific practices that mirror those used by members of the scientific community who often interrogate the credibility of sources of information to generate knowledge (Moje, 2015; Schwarz et al., 2017). Learning to analyze and evaluate sources of information are crucial skills needed to tackle the serious environmental, social, and political challenges facing our nation and world. These studies highlight that the school curriculum can be a place to foster critical literacy and inquiry practices that support disciplinary learning, as well as prepare students to make societal changes.

Expert/novice binary. In one study, critical inquiry disrupted ways in which students were positioned as novice in relation to the science curriculum. Otoide (2017) used action research to examine how her students took on disciplinary expertise in an inquiry-based unit of study. After sharing the story of "The Ignorant Schoolmaster" (Rancière, 1991), Otoide invited her sixth-grade students to pursue a science topic of interest by inquiring "through, with, and about" (p. 308) the text. Students began by reading a range of informational texts, then transitioned to questioning what perspectives were missing from the texts, and ended by self-reflecting on how this information was salient to their lives. This critical engagement with text not only led to new scientific discoveries but also new realizations about students' expertise and agency in the discipline. The author explained, "Students displayed an awareness of accessing and applying their own intelligence by commenting and reflecting on their growth in the ability to learn, the benefits of teaching themselves and the freedom associated with executing their own intelligence" (p. 315). Proponents for inquiry-based teaching argue that engaging in practices specific to the discipline not only supports academic learning but makes accessible the norms, discourses, and literacy practices that are often obscured in the official school curriculum (Moje, 2015). Through inquiry, students can identify similarities between their work and the work that scientists do, helping them feel like expert participants in real disciplinary communities. In this particular study, the practice of critical inquiry in science repositioned students as knowledgeable, rather than novice, scholars.

Together, this small set of studies demonstrates the power of inviting students to critique, question, and converse with texts that are often seen as sources of information and "truth" (Luke, 2018). Yet, these studies also highlight the conflicting theoretical constructs undergirding different approaches to enacting critical inquiry in the science classroom. For O'Hallaron et al. (2015), critical reading held the potential for a more informed and engaged democratic citizenship, while Laughter and Adams (2012) imagined critical inquiry as an important step toward enacting social justice. As Janks, Dixon, Ferreira, Granville, and Newfield (2013) explain, "Critical literacy is about enabling young people to read both the word and the world in relation to power, identity, difference and access to knowledge, skills, tools and resources" (p. 225). Despite varying theoretical orientations, critical inquiry, as a form of critical literacy, provided students opportunities to disrupt structures and ideologies in the science classroom.

Learning in Context

Across the studies, contextually-based learning experiences were essential for the enactment of critical inquiry. Although research into classroom learning experiences presume a particular school-based context, these studies illuminated the importance of moving beyond the walls of the school to engage in scientific inquiry that attended specifically to students' physical and sociocultural worlds. For example, in some instances, the classroom spaces were physically transformed to represent a new environment. The teacher and students in Barton and Tan's (2009) study created a kitchen inside the classroom where they made appetizers in order to learn about nutrition alongside students' cultural and familial culinary knowledge.

In other studies, students stepped outside the classroom walls to explore scientific content in the natural world. In studying three elementary teachers' enactment of science-inquiry teaching,

Howes, Lim, and Campos (2009) found that one kindergarten teacher used a local pond throughout the year to teach science. Students' inquiries were grounded in activity and experience (Dewey, 1938), and according to the authors, "the sources of questions, and therefore of scientific inquiry, were not confined to texts and the teacher" (p. 212). Although students' inquiries were tied to real-world contexts, they all revolved around one particular pond, without consideration of how this ecosystem was similar or different to others in their community or environmental conditions that threaten habitats or species. Critical literacy, however, suggests students must engage in the broader social and political world as they learn to read the "word and the world" (Freire & Macedo, 1987), a pedagogical approach Buxton (2006) attempted to capture with elementary students who inquired into their local ecosystem.

The teachers in Buxton's (2006) study took a different approach. For the teachers at this elementary school, the enactment of "contextually authentic scientific inquiry" (p. 719) involved attention to both the physical and social aspects of context. In this study, students revitalized a school garden as they inquired into the lives of local plant and animal species. Context was also linked to students' social experiences and their inquiries spurred from experiences they had with family or friends, such as catching fish from local water sources. Buxton noted that students were highly engaged in these kinds of inquiries, yet their teachers faced tensions in developing and enacting a curriculum that was context-specific and aligned to students interests. This tension highlights the ways critical pedagogical practices disrupt traditional teaching structures, such as lesson planning in advance. For the teachers in this study, learning to adapt and respond to students was crucial for students to inquire into their local communities.

Wilson-Lopez et al. (2017) took a more radical approach by studying the ways in which high school students critically read the world of engineered designs. In this study, students and teachers seemed to bring the world into the classroom by examining a range of engineered products from both local and global communities. Throughout the unit, students asked critical questions, like "Who benefits and who pays?" (p. 239) as they researched various designs and the people (or companies) who engineered them. This deeply contextual inquiry into engineered designs inspired a raised consciousness for many of the students. For example, at the start of the unit, students believed that a blood filter used to fight Ebola was one of the best inventions of the year. However, through their critical inquiries into the product, they discovered that the filter was expensive and using the product for its engineered purpose in West Africa would be nearly impossible. The class also discovered the filter was designed in Europe and tested in Germany, far from the patients in West Africa who supposedly stood to benefit from it. Through critical inquiry, students uncovered the company's motivation for profit and concluded that engineering such a device led to inequitable access and health care outcomes. The authors argued that critical reading and inquiries into the world of engineered designs made content more accessible and meaningful to students, preparing them "to perform either as engineers or as active stakeholders, while at the same time moving toward changes that promote more equitable outcomes for all" (p. 244). Unlike Buxton (2006), Wilson-Lopez et al. noted the pedagogical power, rather than the constraints, this approach offered in the science classroom. This contrast illuminates the varying ways in which school structures and demands can impact students' engagement in critical scientific inquiry at school.

Discussion and Implications

Findings from this review indicate the powerful possibilities nestled within a critical inquiry approach to science learning. By using literacy as a tool to honor cultural diversity, critique authoritative texts, and engage with the natural and sociopolitical world, this body of scholarship points to the positive influence critical inquiry can have in students' learning of scientific and social issues.

Across this body of scholarship, critical inquiry created opportunities to put reading and writing to use, rather than developing literate practices as decontextualized skills. Across each study, critical inquiry opened new possibilities for students to engage in discipline-specific practices, such as pursuing scientific topics of interest and evaluating sources of information. These skills, however, were not the sole determinants for student learning. Instead, critical inquiry opened new pathways for students to disrupt the status quo, question forms of oppression, and redesign more just social futures. In this way, critical inquiry positioned students as agentic, powerful meaning-makers, armed with scientific knowledge and critical literacy skills to tackle pressing environmental, social, and political concerns.

These studies illuminate that specific components can support the design and enactment of critical inquiry in science education. First, students' full humanity as individuals with unique cultural, literacy, and linguistic practices were honored and recognized as essential components to engaging in critical scientific inquiry. Indeed, Freire (1970) believed that "apart from inquiry, apart from the praxis, individuals cannot be truly human" (p. 53). Given the ongoing forms of racial discrimination, language domination, and inequitable access to resources that students from low-income backgrounds experience in school (Kohli, Pizarro, & Nevárez, 2017), these studies highlight how the experiences and identities of students from racially, linguistically, and socioeconomically diverse backgrounds can be honored and respected as an integrated aspect of learning about the natural and sociopolitical world. Second, critical inquiry encouraged students to question and critique curricular content, texts, and power relationships that often go unexamined at school. Today, students must have access to this kind of education in school in order to confront the complex challenges of the 21st century as active and informed members of society. Finally, these studies pointed to the power of place and the importance of situating inquiry within both the natural and sociopolitical world. Critical inquiry offered a way to bring complex ecological and social realities into the classroom. In an increasingly global and technologically connected world, students' connection to real-world issues is imperative to their development as students and active citizens.

While this instructional practice arguably holds the potential to create inclusive, engaging, and powerful curricular spaces for students, the studies in this review also pointed to challenges and questions that remain in enacting critical inquiry in K-12 science learning contexts. First, further examination is needed to understand how teachers' beliefs and reflections on their own positions of power influence the ways they enact critical inquiry specifically and critical pedagogy more broadly. Although the teachers in Brown & Crippen's (2017) study developed a unit that was inclusive of students' cultures, the teachers stopped short of critically examining their own cultural practices or relationship to the dominant culture. None of the studies explicitly considered teachers' beliefs and knowledge even though these factors influence equitable classroom practices (Brown, 2013; Milner, 2017). Future research in this area would benefit from examining how teachers' beliefs, as well as their critical self-reflections, influence their enact of inquiry pedagogy.

In addition, only one study accounted for the ways in which critical inquiry instruction translated into tangible action for change. Wilson-Lopez et al. (2017) demonstrated how students engineered "counter-designs" (p. 241) to address the social inequity and environmental harm they discovered through their inquiries into engineering science. Aside from this important example, a paucity of research exists in the ways action and advocacy are realized as a part of inquiry practice in the classroom (Harste & Leland, 1998; Hoffman, 2017; Vasquez, 2004). These studies, although rich with possibilities for social, political, and environmental activism, illuminate the continued challenge of realizing such a vision in K-12 classrooms today. Future research may benefit from examining how children and youth use critical inquiry to advocate for change outside of the school walls as they attend to issues of equity and social justice.

The findings from this review suggest that curricular and instructional practices can be enacted to realize critical inquiry in K-12 classroom spaces. However, they also indicate that powerful structures like high-stakes testing mandates or authoritative discourses embedded in texts present serious roadblocks to pursuing critical inquiry in science. One implication of this review is that there is a need to support teachers as they navigate the complex process of uniting science learning with literacy and inquiry to interrogate critical social issues with students. Teachers in the reviewed studies desired support in planning curriculum (Barton & Tan, 2009), navigating school curriculum mandates (Buxton, 2006), and inquiring into their own cultural identities (Brown & Crippen, 2017). Teacher educators and researchers must be ready to meet the needs of pre- and in-service teachers engaged in critical pedagogical work by developing collaborative partnerships, sharing resources, and using critical tools of reflection together. A second implication of this review is to interrogate the purpose of critical inquiry in the classroom. These pedagogical practices, while supporting students' learning of science, can also be used to realize new educative goals, such as equipping students to engage in advocacy and action for greater environmental and social justice. Teachers, along with school, district, and university partners, can redesign inquiry pedagogy so learning that begins in the classroom continues long after a unit or school year ends.

Conclusion

This analytic literature review highlights the affordances, tensions and lingering questions that remain in advancing critical inquiry in the context of science education. It also sheds light on new ways literacy can be used as a tool to read both the word and the world (Freire & Macedo, 1987) in advancing broad goals for social justice. This review offers a beginning look at science learning that is aligned to students' interests, discipline-specific practices, and confronts oppressive structures. Using these varied models of critical inquiry, teachers and teacher educators can use literacy as a means to support student-centered and critical forms of scientific learning. At a time when there seems to be no shortage of environmental, political, and humanitarian crises in the world, this review offers a glimpse into what students, teachers, and education researchers can do to realize greater social transformation and change.

Anne Daly-Lesch, M.Ed., is a PhD candidate in Language and Literacy Studies at the University of Texas at Austin. Prior to graduate school, Annie worked as an elementary and middle school teacher for seven years in San Antonio and Austin, Texas and is a certified reading specialist. Annie's teaching experiences, professional and personal inquiries into critical social issues inform her current research interests. Utilizing theoretical frameworks such as critical race theory (Ladson-Billings & Tate, 1995; Yosso, 2005), critical literacy (Freire, 1970) and racial literacy (Guinier, 2004), Annie's research focuses on how elementary teachers enact critical literacy and racial literacy instruction with their students. Annie is also a graduate research assistant and assistant instructor and works to bring critical perspectives to methods courses with preservice teachers. Annie is an active member of professional organizations including the Literacy Research Association and the National Council of Teachers of English, as well as in her community, serving as a county voter deputy registrar and member of a local anti-racist teacher organization.

References

Au, W. (2008). *Unequal by design: High-stakes testing and the standardization of inequality* (1st edi tion). New York: London: Routledge.

Babaci-Wilhite, Z. (2017). A rights-based approach to science literacy using local languages: Contextualizing inquiry-based learning in Africa. *International Review of Education / International Zeitschrift Für Erziehungswissenschaft, 63*(3), 381–401. https://doi.org/10.1007/s11159-017-9644-3

Barton, A. C., & Tan, E. (2009). Funds of knowledge and discourses and hybrid space. *Journal of Research in Science Teaching, 46*(1), 50–73. https://doi.org/10.1002/tea.20269

Bazzul, J., & Sykes, H. (2011). The secret identity of a biology textbook: Straight and naturally sexed. *Cultural Studies of Science Education, 6*(2), 265–286. https://doi.org/10.1007/s11422-010-9297-z

Brown, J. C. (2017). A metasynthesis of the complementarity of culturally responsive and inquiry-based science education in k-12 settings: Implications for advancing equitable science teaching and learning. *Journal of Research in Science Teaching, 54*(9), 1143–1173. https://doi.org/10.1002/tea.21401.

Brown, J. C., & Crippen, K. J. (2017). The knowledge and practices of high school science teachers in pursuit of cultural responsiveness. *Science Education, 101*(1), 99–133. https://doi.org/10.1002/sce.21250

Buxton, C. A. (2006). Creating contextually authentic science in a "low-performing" urban elementary school. *Journal of Research in Science Teaching, 43*(7), 695–721. https://doi.org/10.1002/tea.20105

Cambria, J., & Guthrie, J. T. (2010). Motivating and engaging students in reading. *The NERA Jour nal, 46*(1), 15–29.

Cervetti, G., Jaynes, C., & Hiebert, E. (2009). Increasing opportunities to acquire knowledge through reading. In E. Hiebert (Ed.), *Reading more, reading better*. New York, NY: Guilford Press.

Cervetti, G. N., Barber, J., Dorph, R., Pearson, P. D., & Goldschmidt, P. G. (2012). The impact of an integrated approach to science and literacy in elementary school classrooms. *Journal of Research in Science Teaching, 49*(5), 631–658. https://doi.org/10.1002/tea.21015

Cervetti, G. N., Pearson, D., Barber, J., Hiebert, E., & Bernardo, M. A. (2007). Integrating literacy and science: The research we have, the research we need. In M. Pressley, A. K. Billman, K. Perry, K. Refitt, & J. Reynolds (Eds.), *Shaping literacy achievement: The research we have, the research we need* (pp. 157–174). New York, NY: The Guilford Press.

Darder, A. (2012). *Culture and power in the classroom: Educational foundations for the schooling of bicultural students* (2nd ed.). New York, NY: Routledge.

Davis, D. S., & Vehabovic, N. (2017). The dangers of test preparation: What students learn (and don't learn) about reading comprehension from test-centric literacy instruction. *The Reading Teacher, 71*(5), 579–588. https://doi.org/10.1002/trtr.1641

Davis, D. S., & Willson, A. (2015). Practices and commitments of test-centric literacy instruction: Lessons from a testing transition. *Reading Research Quarterly, 50*(3), 357–379. https://doi.org/10.1002/rrq.103

Dewey, J. (1938). *Experience and education*. New York, NY: Simon & Schuster.

Duke, N. K. (2016). Project-based instruction: A great match for informational texts. *American Educator, 40*(3), 4-12.

Freire, P. (1970). *Pedagogy of the oppressed*. New York, NY: The Continuum Publishing Company.

Freire, P., & Macedo, D. P. (1987). *Literacy: Reading the word and the world*. South Hadley, MA: Bergin & Garvey Publishers.

Gavelek, J. R., Raphael, T. E., Biondo, S. M., & Wang, D. (2000). Integrated literacy instruction. In M. L. Kamil, P. B. Mosenthal, D. Pearson, & R. Barr (Eds.), *Handbook of reading research* (3rd ed., pp. 587-608). Mahwah, NJ: Routledge.

Giroux, H., & Simon, R. I. (1988). Schooling, popular culture, and a pedagogy of possibility. *Journal of Education, 170*(1), 9–26. https://doi-org.ezproxy.lib.utexas.edu/10.1177/002205748817000103.

Guthrie, J. T., Anderson, E., Alao, S., & Rinehart, J. (1999). Influences of concept-oriented reading instruction on strategy use and conceptual learning from text. *The Elementary School Journal, 99*(4), 343–366. https://doi.org/10.1086/461929

Håland, A. (2017). Disciplinary literacy in elementary school: How a struggling student positions herself as a writer. *The Reading Teacher, 70*(4), 457–468. https://doi.org/10.1002/trtr.1541

Harste, J. C., & Leland, C. H. (1998). No quick fix: Education as inquiry. *Reading Research and Instruction, 37*(3), 191–205. https://doi.org/10.1080/19388079809558264

Hoffman, J. V. (2017). What if "just right" is just wrong? The unintended consequences of leveling readers. *The Reading Teacher, 71*(3), 265–273. https://doi.org/10.1002/trtr.1611

Howes, E. V., Lim, M., & Campos, J. (2009). Journeys into inquiry-based elementary science: Literacy practices, questioning, and empirical study. *Science Education, 93*(2), 189–217. https://doi.org/10.1002/sce.20297

Janks, H. (2010). *Literacy and power*. New York, NY: Routledge.

Janks, H., Dixon, K., Ferreira, A., Granville, S., & Newfield, D. (2013). *Doing critical literacy: texts and activities for students and teachers*. New York, NY: Routledge.

Janks, H. (2010). Critical approaches to teaching language, reading, and writing. In D. Wyse, R. An drews, & J. Hoffman (Eds.), *The Routledge international handbook of English, language and literacy teaching* (pp. 267–281). New York, NY: Routledge.

Kilpatrick, W. H. (1921). *The project method: The use of the purposeful act in the educative process*. New York, NY: Teachers College, Columbia University.

Kohli, R., Pizarro, M., & Nevárez, A. (2017). The "new racism" of K–12 schools: Centering critical research on racism. *Review of Research in Education, 41*(1), 182–202. https://doi.org/10.3102/0091732X16686949

Ladson-Billings, G. (1995). Toward a theory of Culturally Relevant Pedagogy. *American Educational Research Journal, 32*(3), 465–491. https://doi.org/10.3102/00028312032003465

Ladson-Billings, G. (2014). Culturally Relevant Pedagogy 2.0: a.k.a. the Remix. *Harvard Educational Review, 84*(1), 74–84. https://doi.org/10.17763/haer.84.1.p2rj131485484751

Laughter, J. C., & Adams, A. D. (2012). Culturally relevant science teaching in middle school. *Urban Education, 47*(6), 1106–1134. https://doi.org/10.1177/0042085912454443

Love, B. L. (2014). "I see Trayvon Martin": What teachers can learn from the tragic death of a young Black male. *The Urban Review, 46*(2), 292–306. https://doi.org/10.1007/s11256-013-0260-7

Luke, A. (2018). *Critical literacy, schooling, and social justice: The selected works of Allan Luke*. London: Routledge, Taylor & Francis Group.

Luke, A. (2019). Regrounding critical literacy. In D. Alvermann, N. Unrau, M. Sailors, & R. Ruddell (Eds.), *Theoretical models and processes of literacy* (7th ed., pp. 349–360). New York, NY: Routledge.

Makalela, L. (2018). Multilanguaging and infinite relations of dependency: Re-theorizing reading lit eracy from ubuntu. In D. Alvermann, N. Unrau, M. Sailors, & R. Ruddell (Eds.), *Theoretical models and processes of literacy* (7th ed.). Retrieved from http://www.taylorfrancis.com/books/9781351616539

Maloch, B., & Horsey, M. (2013). Living inquiry: Learning from and about informational texts in a

second-grade classroom. *The Reading Teacher, 66*(6), 475–485. https://doi.org/10.1002/TRTR.1152

McLaren, P. (1994). *Life in schools: an introduction to critical pedagogy in the foundations of education* (2nd ed.). New York, NY: Longman.

Moje, E. B. (2015). Doing and teaching disciplinary literacy with adolescent learners: A social and cultural enterprise. *Harvard Educational Review, 85*(2), 254–278. https://doi.org/10.17763/0017-8055.85.2.254

Moje, E. B., Ciechanowski, K. M., Kramer, K., Ellis, L., Carrillo, R., & Collazo, T. (2004). Working toward third space in content area literacy: An examination of everyday funds of knowledge and discourse. *Reading Research Quarterly, 39*(1), 38–70. https://doi.org/10.1598/RRQ.39.1.4

Moll, L. C., Amanti, C., Neff, D., & Gonzalez, N. (1992). Funds of knowledge for teaching: Using a qualitative approach to connect homes and classrooms. *Theory Into Practice, 31*(2), 132–141. https://doi.org/10.1080/00405849209543534

Nichols, S. L., & Berliner, D. C. (2008). Why has high-stakes testing so easily slipped into contemporary American life? *The Phi Delta Kappan, 89*(9), 672–676. https://doi.org/10.1177/003172170808900913.

Ødegaard, M., Haug, B., Mork, S. M., & Sørvik, G. O. (2014). Challenges and support when teach ing science through an integrated inquiry and literacy approach. *International Journal of Science Education, 36*(18), 2997–3020. https://doi.org/10.1080/09500693.2014.942719

O'Hallaron, C. L., Palincsar, A. S., & Schleppegrell, M. J. (2015). Reading science: Using systemic functional linguistics to support critical language awareness. *Linguistics and Education, 32*, 55–67. https://doi.org/10.1016/j.linged.2015.02.002

Osborne, J. (2010). Arguing to learn in science: The role of collaborative, critical discourse. *Science, 328*(5977), 463–466. https://doi.org/10.1126/science.1183944

Otoide, L. (2017). In pursuit of the practice of radical equality: Rancière inspired pedagogical inquiries in elementary school science education. *Cultural Studies of Science Education, 12*(2), –319. https://doi.org/10.1007/s11422-015-9722-4

Owens, R. F., Hester, J. L., & Teale, W. H. (2002). Where do you want to go today? Inquiry-based learning and technology integration. *The Reading Teacher, 55*(7), 616–625.

Pappas, C. C., Varelas, M., Barry, A., & Rife, A. (2002). Dialogic inquiry around information texts: The role of intertextuality in constructing scientific understandings in urban primary classrooms. *Linguistics and Education, 13*(4), 435–482. https://doi.org/10.1016/S0898-5898(03)00004-4

Paris, D. (2012). Culturally sustaining pedagogy: A needed change in stance, terminology, and practice. *Educational Researcher, 41*(3), 93–97. https://doi.org/10.3102/0013189X12441244

Paris, D., & Alim, H. S. (2014). What are we seeking to sustain through culturally sustaining pedagogy? A loving critique forward. *Harvard Educational Review, 84*(1), 85–100. https://doi.org/10.17763/haer.84.1.982l873k2ht16m77

Pearson, P. D., Moje, E., & Greenleaf, C. (2010). Literacy and science: Each in the service of the other. *Science, 328*(5977), 459–463.

Rancière, J. (1991). *The ignorant schoolmaster: Five lessons in intellectual emancipation*. Stanford, CA: Stanford University Press.

Ridley, D. (2008). The multiple purposes of a literature review. In *The literature review: A step-by-step guide for students*. (pp. 23–40). London: SAGE Publications.

Schwarz, C. V., Passmore, C., & Reiser, B. J. (Eds.). (2017). *Helping students make sense of the world using next generation science and engineering practices*. Arlington, VA: NSTA Press, National Science Teachers Association.

Smith, N. B. (1934). *American reading instruction: Its development and its significance in gaining a*

perspective on current practices in reading. Newark: DE: Silver, Burdett, and Company.
Tong, F., Irby, B. J., Lara-Alecio, R., Guerrero, C., Fan, Y., & Huerta, M. (2014). A randomized study of a literacy-integrated science intervention for low-socio-economic status middle school students: Findings from first-year implementation. *International Journal of Science Education, 36*(12), 2083–2109. https://doi.org/10.1080/09500693.2014.883107
Tucker-Raymond, E., Varelas, M., & Pappas, C. C. (2013). Children's conceptions of being scientists. In *Children's ways with science and literacy: Integrated multimodal enactments in urban elementary classrooms* (pp. 186–209). New York, NY: Routledge.
Varelas, M., & Pappas, C. C. (2006). Intertextuality in read-alouds of integrated science-literacy units in urban primary classrooms: Opportunities for the development of thought and language. *Cognition and Instruction, 24*(2), 211–259. https://doi.org/10.1207/s1532690xci2402_2
Vasquez, V. M. (2004). *Negotiating critical literacies with young children*. Mahwah, N.J: Routledge Press/ Lawrence Erlbaum Associates, Inc.
Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes* (Revised ed. edition; M. Cole, V. John-Steiner, S. Scribner, & E. Souberman, Eds.). Princeton, N.J.: Harvard University Press.
Wells, G. (1999). D*ialogic inquiry: Towards a socio-cultural practice and theory of education*. Cambridge, MA: Cambridge University Press.
Whipple, G. M. (1925). Report of the national committee on reading (Vol. 24). Public School Publishing Company.
Wilson-Lopez, A., Strong, K., & Sias, C. (2017). Critical literacy, disciplinary literacy: Reading the engineering-designed world. *Theory Into Practice, 56*(4), 238–245. https://doi.org/10.1080/00405841.2017.1389219
Wright, T. S., & Gotwals, A. W. (2017). Supporting kindergartners' science talk in the context of an integrated science and disciplinary literacy curriculum. *The Elementary School Journal, 117*(3), 513–537. https://doi.org/10.1086/690273