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Research Article

Writing From Different Cultural Contexts: How College Students Frame an Environmental SSI Through Written Arguments

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Abstract: The research objective of this study was to describe the frames that students from two culturally distinct institutions used in their argumentative essays on a locally relevant environmental socioscientific issue. Participants ($n = 47$) were recruited from biology courses designed for pre-service elementary teachers at both a public university and a tribal community college separated by around 80 km. Students participated in iterative writing assignments, class discussion, and small group planning activities. Each student submitted three essays (in total around 140 essays), which were analyzed for the types of claims made, the types of evidence used to support claims, and patterns of argument framing. A framing typology from the science communication discipline was used. Both cohorts used frames around *accountability* and *compromise*, but tribal college students were more likely to draw on *morality* frames while university students drew on *economic development* frames. In addition, the tribal students were less likely (58% of essays) to use scientific evidence to support their claims than the university students (96% of essays). We conclude that while frames lend them themselves to using scientific evidence, students from culturally marginalized backgrounds have an opportunity to increase their sense of agency and communicate their argumentative positions on SSIs. We recommend that educators assign WTL activities that allow students to select their own frames but encourage students to integrate scientific evidence in their essays, while also recognizing that how we define science is likely culturally biased. J Res Sci Teach
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Scientifically literate individuals are able to evaluate evidence, determine which best supports their claims, and anticipate counter arguments that are presented in scientific arguments (Erduran, Simon, & Osborne, 2004; NRC, 2012). In other words, they can make sense of science through the use of evidence-based reasoning (Brown, Nagashima, Fu, Timms, & Wilson, 2010) and problem-solving of socio-scientific issues (SSIs) (Feinstein, Allen, & Jenkins, 2013; Sadler & Zeidler, 2005). When making meaning of SSIs, students may use

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informal and moral reasoning in their arguments, especially if they draw on personal knowledge (Sadler, 2004; Sadler & Zeidler, 2005), and in the process incorporate academic language into their own communication strategies (Wallace, 2004). Because students often recall personal knowledge to support their scientific funds of knowledge to make decisions or develop positions around SSIs, they often adopt frames, or positions, that enable them to interpret language embedded in their own worldview (Goffman, 1974).

A frame describes how a writer/speaker presents a topic with the intent of influencing how the audience will interpret it (Nisbet, 2014). Yet, the perceptions of a social situation help define the frame a communicator uses (Goffman, 1974). People can use different frames but construct the same claims about an SSI. For example, two arguments may present the same claim that genetically modified (GM) crops are harmful, but one argument may be framed around economic issues (e.g., family farmers cannot afford GM crops and will lose jobs), while another argument may be constructed around an environmental frame (e.g., GM crops may cross pollinate with native plants potentially decreasing variation in native plant populations). Likewise, two different moral claims may use the same frame, as in the case of whaling laws (e.g., [i] the United States should be allowed to engage in whaling because it is a part of the indigenous Alaskan culture or [ii] even though whaling may be linked to historical and cultural practices of indigenous peoples, the environmental costs are too great).

SSI reasoning is affected by the multiple perspectives students bring to class. Yang and Anderson (2003) found that Taiwanese students' cognitive orientation toward scientific and social evidence when learning about an environmental SSI (nuclear energy use) fell along a range of reasoning strategies that could be predicted based on their science performance. What is not clear is how these perspectives or orientations may influence how students communicate and frame their decisions about SSIs. Interestingly, Zeidler, Herman, Ruzek, Linder, and Lin (2013) found that across several cultural and geographical contexts students adhered to a similar set of reasoning patterns when exploring SSIs. Hence, studies of how individuals collectively *frame* their claims, evidence, and reasoning are relevant in studies exploring scientific argumentation, especially taking into account whether cultural and personal backgrounds influence how students make meaning of SSIs.

In light of recent efforts to broaden participation of those who study or work in STEM fields, educators need strategies to assess and improve students' understanding of science while building opportunities for students to draw from their own funds of knowledge. Maltese and Tai (2011) asserted that making science content relevant/personal and by using problem-based learning strategies, science educators can increase the diversity of students who are interested in and willing to stay in the sciences. Because the participation of women and underrepresented minorities in the sciences is less than that of Euro-American men resulting in, what many argue, missed opportunities to draw on human resources and contributions (Hill, Corbett, & St. Rose, 2010; Seymour & Hewitt, 1997), it makes sense to continue to explore students' worldviews and personal funds of knowledge (Calabrese Barton & Tan, 2009; Warren, Ballenger, Ogonowski, Roseberry, & Hudicourt-Barnes, 2001), so we can best meet the need of all students in their formal science courses.

As science educators are encouraged to make content relevant to their students, it is inevitable that they will bring out-of-school experiences with them to the classroom (Bell, Bricker, Reeve, Zimmerman, & Tzou, 2013; Ochs & Taylor, 1992), which will likely influence how they frame any arguments about SSIs they explore. Warren et al. (2001) reminded researchers that the "everyday" experiences of "historically underserved communities. . .are viewed as being the furthest from those traditionally valued in models of Western science or in national standards" (p. 121). As a result, educators must determine

when and how it is appropriate to introduce non-academic knowledge into formal classroom experiences (Calabrese Barton & Tan, 2009) and to help students negotiate such knowledge within school (Wallace, 2004). Because people frame and construct arguments around SSIs from their own cultural worldview, evaluating arguments using a binary rubric of "right/wrong" or even "expected/unexpected" limits what researchers can learn about how people make meaning of SSIs (Endres, 2014).

Our paper describes a study designed around problem-based writing-to-learn (WTL) assignments in undergraduate biology courses taught at both a Tribal College and a Public State University. We did not expect the participating students to replace or express a specific epistemology. Rather, our goal was to allow them to ground arguments in their own cultural epistemologies (Bang & Medin, 2010) by designing writing prompts that let students (i) use their own voice (Wallace, 2004); (ii) explicitly draw on personal funds of knowledge (Moje et al., 2004); (iii) consider a locally relevant SSI of which many of them were already aware (e.g., Kolstø, 2006); and (iv) recognize that we were not looking for "right or wrong answers" (Balgopal, Wallace, & Dahlberg, 2012). We analyzed the types of claims students made, the types of evidence used to support claims, and how arguments were framed. We believe the findings of our study can inform how argumentation around SSIs can be integrated into science courses to the benefit of all students.

Theoretical Framework

Sociocultural Theory

This study was grounded in the premise that knowledge is socially constructed (Wertsch, 1995). In order to make meaning of science, people use language to express their conceptual understandings (Calabrese Barton & Tan, 2009). They also use language to convey to others their cultural worldviews and in the process, develop discursive identities (Brown, Reveles, & Kelly, 2005). Discursive identities may indicate individuals' perceptions of themselves as being scientists or not. Calabrese Barton and Tan (2009) explained that students' everyday experiences affect not only how they make sense of science but also influence their self-perceptions as science knowledge consumers and producers. Students may speak about themselves as the ones generating new scientific knowledge that may benefit others, or as the beneficiaries of scientific knowledge. Hence, what language students use and how they use it can provide insight to how they learn and form their identities.

Human-constructed symbols and norms (i.e., language and expectations) drive learning and are by-products of learning (Gee, 2004; Lantolf, 2000; Lemke, 1990). Wickman and Ostman (2002) described knowledge and learning as "parts of a dynamic process where relationships are construed in encounters between individuals and the world. And in these encounters the historical, institutional, social, and individual are integrated parts" (p. 603). Framed in pragmatism and the writings of Dewey and Wittgenstein, Wickman and Ostman explained that meaning making occurs as a result of the tightly intertwined processes of *talking* and *doing*. Subsequently, to examine how learners make meaning we must carefully interpret how an individual communicates, which may require that researchers make inferences about discourse and the individuals' lived experiences (Charmaz, 2005). This can be accomplished by allowing people to engage in authentic discourse, so they can express (in talking and/or writing) their prior knowledge and perceptions (Wallace, 2004). Exploring SSIs with others in science classes can help students to find their voices in science discourse spaces. At the same time, writing for oneself catalyzes meaning making for some people, as it involves drawing on personal funds of knowledge (including traditional ecological knowledge, if relevant) necessary for framing and

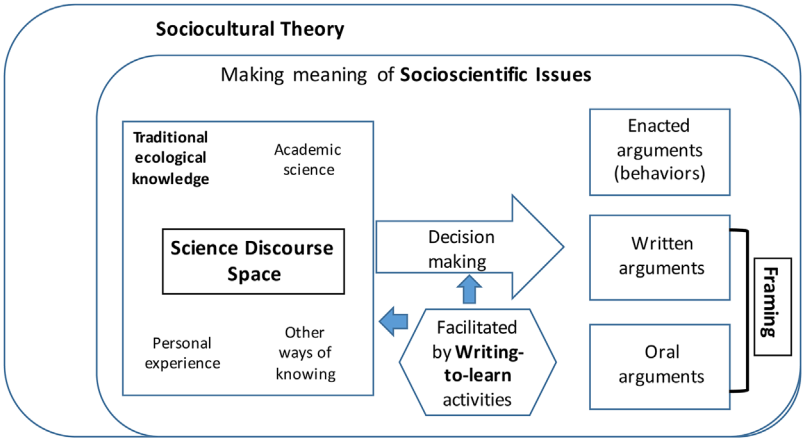

Figure 1. Socioscientific meaning making. **Sociocultural theory** explains that making meaning of our world, including making decisions about **Socioscientific Issues**, is socially and culturally embedded. People draw on different funds of knowledge in the **Science Discourse Space**, including traditional ways and academic ways of knowing, to help them in this process. The results of decision making may be expressed as enacted arguments (i.e., behaviors), written arguments, and oral arguments. Both written and oral arguments are often **framed** around decisions and perspectives shaped by the types of evidence the decision maker chooses to use. **Writing-to-learn** interventions can promote the active engagement with different funds of knowledge in the science discourse space that may, in turn, facilitate decision making.

communicating arguments (Figure 1). While oral discourse is critical for socially derived meaning making, it is through writing that learners can commit to their own ideas, engage in revisions, and transform knowledge (Bereiter & Scardamalia, 1987). As Tomas, Ritchie, and Tones (2011) pointed out, although studies examining student writing around SSIs are less frequent compared to oral argumentation studies, both are valuable.

Socioscientific Issues. Making science content relevant to students and providing opportunities for them to engage in meaningful discussions about scientific issues allows them to better articulate their understanding of scientific content (Evagorou, Jimenez-Aleixandre, & Osborne, 2011; Rivard & Straw, 2000). SSIs are case studies that are incorporated into science curricula to make science content relevant. Although there are no clear *right* or *wrong* answers to SSIs, students must acquire some foundational scientific content knowledge to understand them. For example, to be informed decision makers about environmental SSIs, individuals must first understand the complexity of ecological systems and the impact that humans can have on these systems before they can construct an argument (Davidson, 2003; Jordan, Singer, Vaughan, & Berkowitz, 2009; Walshe, 2008).

SSIs are often socially charged, open-ended, debatable, and diverse—they range from nuclear power, genetic engineering, and land use issues to biofuels and climate change. Lessons on SSIs allow classroom educators to examine the reasoning strategies that students employ as they make sense of the social and moral consequences of decisions related to the issue (Sadler, 2004; Sadler & Zeidler, 2005; Zeidler & Schafer, 1984). In our previous studies, we found that there were distinct differences between the types of claims and evidence that students from different majors and institutions (Public University and Tribal Community College) used (Balgopal et al., 2012). Biology majors made claims that were more anthropocentric than the education majors, who were more likely to be environmentally centric. We argued that prompts that elicit expressive reflective writing are important, if educators value that learners bring their own worldviews to class and need

opportunities to negotiate or integrate their scientific knowledge with their personal knowledge (Balgopal et al., 2012).

Science Discourse Spaces. Students in formal learning environments engage with multiple types of discourse and knowledge across their personal lives—in "first spaces"—and academic lives—in "second spaces" (Ramnarain & de Beer, 2013). Bhabha (1994) described that the negotiation of these different funds of knowledge occurs in a "third space" during a process that often illuminates tensions and hierarchies of knowledge with which the individual must contend. The "third space" is a hybrid space created by each individual as he/she makes meaning of his/her world. Because learners bring nonacademic knowledge to formal learning environments, we acknowledge the role that these diverse ways of knowing play in science argumentation (Basu & Calabrese Barton, 2009; Moje et al., 2004). Wallace (2004) proposed a theoretical framework that centers on studying language use around science within the constructs of authenticity, multiple discourses, and "third space." Wallace's model presents three continua that inform argumentation research: *expression* (moving between vernacular to scientific language), *voice* (moving between private to public discourse), and *meaning* (finding meaning between two interlocutors). This framework is important because it illustrates that scientific literacy is not a dichotomous state (literate or not literate).

Often hybrid spaces are created when learners reconcile different discourses and perhaps identities (Moje et al., 2004). Moje et al. (2004) presented three conceptualizations of the third space. The first supports learners constructing links between academic and personal funds of knowledge. The second describes competencies in being able to move back and forth across borders to engage in separate spaces. Aikenhead and Jegede (1999) described this act of moving from everyday science to school science and discourse as *border crossings*. The third is a renegotiating or blending of multiple discourses into a single space. Calabrese Barton, Tan, and Rivet (2008) asked what instruction would look like "if students were to be supported in becoming fluent in the subculture of school science while not simultaneously abandoning their life worlds (p. 73)." Although hybridity theory may help science education researchers explain how students negotiate different funds of knowledge, teachers are not necessarily prepared to help their students blend or integrate academic knowledge with students' non-academic ways of knowing and communicating about science (Brickhouse & Potter, 2001; Calabrese Barton et al., 2008). A limitation of hybridity theory, though, is that it cannot predict which frames students will use to make decisions about SSIs.

Traditional Ecological Knowledge. For the current paper, half of our participants were students of a Tribal College on a Native American reservation. These students likely brought cultural funds of knowledge that reflected their experiences on the reservation and/or philosophies espoused by tribal members and Community College instructors. Cultural funds of knowledge of indigenous people are often referred to as "traditional ecological knowledge" (TEK), a construct that evokes much discussion among researchers, who debate whether it should be considered scientific knowledge or not (Cajete, 2000). van Eijck and Roth (2007) suggested that TEK is clearly distinct from Western Modern Science (WMS) but should be valued even if the knowledge gained through different culturally bound practices is different from the knowledge produced through WMS standards. In response, Mueller and Tippins (2010) argued that the van Eijck and Roth model dichotomizes various ways of knowing in an overly simplistic "TEK versus WMS" framework. They posited that knowledge, regardless of how it is generated, is important if it informs communities and individuals of how the natural world functions. They also suggested that it is important to move away from the notion that WMS is of greater value because it erroneously

reinforces colonial views of legitimate ways of knowing the world. The ongoing discussion of TEK is relevant to our study because we are interested in cultural funds of knowledge that participants use to make meaning of environmental issues. We adhere to the assumption that all people have cultural or personal funds of knowledge that may have been generated through personal experience, through generational knowledge passed on through oral narratives, or through assumptions and principles of how the world "works" (Bang & Medin, 2010; Endres, 2014; Mueller & Tippins, 2010).

Writing-to-Learn. Although writing, in some communities, is less important than oral forms of communicating, it is an important way of documenting and sharing ideas within science classrooms and among scientists. The use of written discourse provides opportunities for learners to make meaning and for instructors and researchers to assess how learners make meaning. Writing-to-learn (WTL) tasks are ideal opportunities for students to evaluate their several funds of knowledge (personal, academic, moral, etc.) as they construct arguments on paper (Bereiter & Scardamalia, 1987; Flower & Hayes, 1981). In addition, writing can help students increase their own scientific knowledge (Hand, Wallace, & Yang, 2004; Mason, 1998; Norris & Phillips, 2003) and can address the issue of lack of participation that occurs in small group discussions (Jimenez-Aleixandre & Pereiro-Munoz, 2002). At the same time, learners make meaning through social interactions, as Rivard and Straw (2000) found; in their study, students who both discussed and wrote about environmental science concepts, compared to those who only wrote about the same concepts, demonstrated greater knowledge outcomes. Regardless of how they are integrated into courses, writing tasks can help learners organize their thoughts prior to writing for an audience, reflect on developing theses, organizing thoughts, and present claims with supporting evidence. Providing evidence to support a claim helps the writer persuade an audience of the validity of his/her argument. Although any type of evidence can be used to support claims, it is assumed by science teachers that scientific data should be used to support claims in scientific arguments, even though, students draw on various types of evidence (Balgopal & Montplaisir, 2011; Balgopal & Wallace, 2009; Patronis, Potari, & Spiliotopoulou, 1999). Furthermore, in written arguments, learners commit to a position or frame(s).

Framing Written Arguments. Although making meaning of SSIs and communicating positions or decisions about them are different discourse events, they are linked by each person's epistemic stance (Kelly & Takao, 2003), in addition to the scientific evidence they choose to present, often depending on what content they understand (Nielsen, 2011). Davis and Russ (2015) argue that social scientists use frame analysis in varying ways but that they usually aim to highlight either the communicator, the text, the receiver, or the culture—four elements of frame analysis identified by Entman (1993). The way people are presented SSIs, we posit, influences how they learn to make sense of and value interpretive processes, as Druckman (2001) reported in his analysis of political discourse. Druckman (2001) explained that frame analysis can be used to study *frames in thought* or *frames in communication*. Although there are differences between these two, they are both similar in that frames allow communicators to (i) define problems; (ii) diagnose causes; (iii) make moral judgments; and (iv) suggest remedies (Entman, 1993). Therefore, frames make information more salient or more noticeable to those in the discourse space.

Research centered on frames in thought examine how individuals "read" a discursive interaction and evaluate how people are thinking and ask, "What is going on here?" (Goffman, 1974). For example, Berland and Hammer (2012) used frame analysis to study how sixth graders and their teachers engaged in oral argumentation during class. Students were engrossed in discussion about data while recognizing that the teacher was the authority figure in the class. The

authors describe the observed phenomena of a shared framing—all of the participants involved in the discourse appeared to have a common understanding of the discourse norms and playful competitive banter. Not surprising, frames in communication can affect frames in thought, and the resulting process is described as framing effects, either *equivalency frames* (manipulating audience reaction by altering the order of information presented) or *emphasis frames* (manipulating audience reaction by highlighting certain aspects of the argument over others) (Druckman, 2001). More recently, communication scholars argue that frames are intentional devices that indicate the communicator's sense of reality, a deviation from the earlier research by Bateson (1955), who described frames as emerging from interactions that were dependent on several variables (Vliegenthart and van Zoonen, 2011). In this sense, "frames in thought" researchers examine the dynamic process, the framing verb, rather than the more static text found in written communication, the frame noun (Druckman, 2001; Davis & Russ, 2015).

Research centered on frames in communication focus on the words and phrases used, as well as the order and organization of narratives. For example, Nisbet, Brossard, and Kroepsch (2003) claimed that journalists' preference for narratives downplays the evidence and inferences needed to make decisions to resolve SSIs. When journalists frame SSIs using storytelling, emotive words, and chronologically presented events, it does not enable the audience to synthesize and evaluate the issue in a neutral manner (Nisbet et al., 2003). Nisbet (2014), subsequently, described a typology of frames based on social meanings and "interpretive frames" used by different stakeholders (e.g., politicians, scientists, lobbyists, journalists) to "simplify complex issues by lending greater weight to certain considerations and arguments over others." (p.44) These frames include (i) social progress (improving quality of life or finding solutions to problems); (ii) economic development (to increase economic competitiveness at local, national, and global levels); (iii) morality and ethics (is science research and/or application ethical?); (iv) there is scientific and technical uncertainty; (v) awareness of "runaway" science or Pandora's box (fatalism, no turning back); (vi) public accountability and governance of science (responsible use or abuse of science); (vii) finding compromises (finding a third path when there are polarized views); and (viii) conflict and strategy (competition behind personalities).

A separate study described five epistemic patterns exhibited by another stakeholder group (secondary science students from Jamaica, Sweden, Taiwan, South Africa, and the United States): (i) fairness; (ii) pragmatism; (iii) emotive reasoning; (iv) utility; and (v) theological (Zeidler et al., 2013). Although there may be some overlap between these two lists of frames, Nisbet's typology centers on content, and Zeidler et al.'s categories center on socioscientific reasoning (SSR). Endres (2014) demonstrated that people coming from different cultural backgrounds frame arguments in different ways, so an analysis of the frames used by students in scientific arguments may provide a window into how they interpret scientific and/or news stories about SSIs, frame decision-making about SSIs within cultural worldviews, and select scientific content learned in their formal class to support their frames. Zeidler et al. (2013) found that reasoning about SSIs drew on epistemic stances that were, interestingly, similar across different cultural contexts. We argue that this is evidence that frame analysis (using frames in communication) across cultural contexts warrants further study. Davis and Russ (2015) argued that there is a need for further frame research that does not treat the communicator as "a non-cognitive agent" (p.227), centers on issues that are not regularly discussed in public media, and recognizes that framing text may be tacit and draw on different types of reasoning. In this vein, our exploratory study extends the current research centered on cultural context and reasoning around a locally relevant SSI using the frames in communication construct. To accomplish this, we asked the research question: *How do students in two culturally different contexts respond to writing prompts about the same environmental issue*?

Methods

Participants and Context

Two populations of college students from two institutions (a 4-year State University and a 2-year Tribal Community College on a Native American reservation) participated in WTL activities in a Biology course for non-majors (those intending to pursue an elementary school teaching license). The participating institutions are located within an hour of each other and share a similar geographic setting, yet are situated in different cultural and economic worlds and attract different types of students. Few Euro-Americans attend the Tribal College, and few Native students attend the State University, despite recruitment efforts. However, there is regular communication between the Science Department at the Tribal College and the Biosciences Department at the State University; this study is an example of that partnership, which was supported by a jointly held federal research grant. In a previous study, at both institutions and with similar students, WTL interventions were associated with claims that were supported by multiple and varied sources of evidence (Balgopal et al., 2012), although, in the current study we did not measure students' incoming ecological knowledge, as we were not interested in measuring conceptual change.

Instructors. The instructor at the Tribal Community College (SD) is a co-author, who is open about his indigenous identity with his students, and holds a Ph.D. in Geosciences. Because the Community College does not award Bachelor's degrees, the instructor aligned his syllabus for his introductory biology course with that used by the nearby State University, in the event that students might transfer to complete their college degree programs. The introductory biology course at the university was designed for pre-service elementary teachers and was taught by one of the authors (MB), whose Ph.D. is in Zoology and Biology Education. The second author (AW), whose Ph.D. is in Ecology/Evolution, was the original course designer and collaborated with both instructors during the study.

Instructional Context. AW observed both courses to ensure fidelity of implementation of the ecology curriculum. Students at both institutions did not need science prerequisites to enroll in the class. They were not assessed on their incoming ecological knowledge before the study began. Although there were two different instructors, our team worked hard to ensure that we used similar instructional strategies to promote small group and class discussion. We used two examples of decisions people make, (i) to compost organic waste or not and (ii) to use cloth or plastic diapers for infants, when introducing the WTL assignment as illustrations that people may exhibit a behavior or make a decision based on various types of evidence, including health, economic, environmental, and cultural. Neither instructor explicitly introduced argumentation theory or frameworks (e.g., Toulmin model). For the actual WTL activity at both institutional contexts, students sat in groups at tables and were encouraged to concept map or diagram their ideas, either individually or collaboratively. The instructors roamed around the small groups and asked students to explain their responses to the three WTL prompts, trying to remain as neutral as possible. Students in both cohorts were asked to begin writing during class. All of the university students chose to use computers in the room; half of the Tribal College students chose to use computers while others wrote their essays long-hand. Although we did not discuss specific moral or cultural frames specifically, we encouraged students to draw on whatever evidence they found relevant.

Public 4-Year University Students. Most of the elementary education students who attend the State University are of European descent and from middle class homes, often in small towns or

rural areas in the upper Midwestern United States. About half of the State University students identified themselves as being from farming families; others had grandparents or uncles and aunts who lived on farms. All of the participants from this cohort were Euro-American, and 22 of the 24 students were women. The State University was established as a Teacher College in 1888. It is the western most public university in the state, that happens to be named after a Dakota Indian word, that means "water that reflects the sky." The state is also known as "the land of ten thousand lakes," and hunting and fishing are a central part of recreational life of many residents, even in the depths of winter, when people ice fish. Students regularly referenced their Scandinavian and/or German American heritage. Overall, the state suffers around an 11% poverty rate; however, on the reservation on which the Tribal College was located, the poverty rate is closer to 25%, while the rate of female-headed households living in poverty is 52% (White Earth Economic Development Office, 2013).

Tribal College Students. Tribal College participants were predominantly identified as Anishinaabe-Ojibwe with the exception of three non-Native reservation residents and one Grand Portage tribe member. One Anishinaabe student lived off the reservation during the study. Sixteen of the twenty-three participants were women and the age ranged from around 19 to 35. There are around 120 students enrolled in the entire Tribal College at one time; classes are relatively small and close-knit. The College, with leadership from SD, has focused on integrating Anishinaabe traditions and practices into science courses. For the Anishinaabeg, hunting, fishing, gathering wild rice, and maple syrup making are all central to their cultural identity (Gross, 2002; Steen-Adams, Mladenhoff, Langston, Liu, & Shu, 2011). The central concept of the Anishinaabe religious worldview is referred to as the "good life" or *bimaadiziwin* (Gross, 2002). Although individual Anishinaabeg adhere to this philosophy at varying levels, just as members from any culture display a range of views, it is a concept that permeates much of the culture on the Anishinaabe reservations, regardless of ethnic identity (Gross, 2002). *Bimaadiziwin* invokes the relationship that people have with the environment and "marked by environmental morality" (Gross, 2002, p.27) and is passed down through stories that promote individual reflection (LaDuke, 1999). This term was not explicitly discussed in the Tribal College class during this study.

WTL Intervention

Students in both settings (Tribal College and Public University) were asked to read articles about "dead zones" in the Gulf of Mexico—readings were drawn from *Science News* (Raloff, 2004a,b), *Worldwatch* Institute (Bright, 1999), and the Ecological Society of America webpage ("hypoxia fact sheet") before writing. The reading material explained fertilizer run off and the resulting cascade of events, in addition to presenting social, economic, and political consequences of the excess nitrate run off into Gulf waters (e.g., financial losses for fishermen). Collectively the articles used four frames that were centered on two central frames: public accountability and middle path/compromise; the latter frames drew on two subsidiary frames: morality/ethics and economic development. Aquatic hypoxia and dead zones are locally relevant because both colleges are situated within a 2 hour-drive of the headwaters of the Mississippi River, are nestled in between agricultural communities, and are globally important since coastal waters are being depleted of commercially important fish (Diaz & Rosenberg, 2008) (Additional information is available as Supplementary Material).

Our WTL prompts were developed as a result of another study on how students wrote about evolution (Balgopal & Montplaisir, 2011) informed by Wallace's (2004) theoretical framework on studying scientific written discourse. Students in both settings wrote three iterations of essays

about aquatic hypoxia and dead zones (see Supplementary Materials). The first essay prompt asked students to write an expository essay about what they knew and understood was happening in aquatic ecosystems; the second prompt asked them to write a narrative essay that reflected on the issue and encouraged them to make personal connections; and the third prompt asked them to develop a persuasive essay and identify dilemmas that they or others might have if they felt compelled to resolve a dilemma stemming from the readings and their class discussions (Balgopal & Wallace, 2009).

Data Collection

In all, we collected 141 essays (three each from 47 participants). Instructors at both of the study sites provided guidance to students by suggesting how to actively read the articles, encouraging student interactions and discussion about the reading and writing assignments, demonstrating how concept mapping can help people organize their thoughts, implementing inquiry-based activities that centered on scientific concepts in the readings (e.g., trophic interactions, nitrogen cycling), and providing time in class for writing. Students were encouraged to listen to other views but to formulate their own arguments in their individual essays. We believe students needed time to make sense of the reading before formalizing their ideas in writing. Ultimately our objective was to design prompts that elicited decision making because, as Nielsen (2011) and Kock (2009) assert, SSI argumentation is about deliberating and selecting a practical resolution.

Data Analysis

We conducted both semantic and latent thematic analyses of students' essays (Braun & Clarke, 2006). We were not concerned with mechanical and superficial aspects of writing (such as grammar, spelling, syntax); at times, we conferred with one another to ensure that we were interpreting written text similarly. We initially conducted inductive semantic thematic coding, identifying types of evidence used (personal and scientific) because our previous studies indicated that when both types of evidence were used students were able to demonstrate greater conceptual understanding than students who drew on only a single type of evidence (Balgopal & Wallace, 2009). Essays that drew on academic/scientific and personal funds of knowledge were coded as *authentic*; those that drew only on personal experiences or beliefs were coded as *subjective*; those that drew only on academic/scientific evidence were coded as *objective*; and those that presented no evidence-based claims were coded as *superficial*, based on a previously described coding scheme (Balgopal & Wallace, 2009). However, as Nielsen (2011) explained, science content can be used not only as evidence to support propositions about decisions to resolve SSIs, but also as frames around which arguments can be constructed.

To analyze how SSI arguments were framed by students, we conducted latent analysis. For this analysis, essay sets were read and coded based on the dilemmas and the solutions about which the students wrote. Using a constant comparative approach (Strauss & Corbin, 1990), initial themes were identified. After re-reading the essays, these themes were collapsed into narrower themes, or axial codes. The final coding process occurred through discussions of the research team and the reading of sets of essays, allowing us to determine salient themes and identify the final selective codes. In naming our themes, we realized that claims were either about problems or about solutions. Claims about problems included: cultural change, financial investments, and considering economic and ecological tradeoffs. Claims about solutions included: social (collaborating or educating), cultural (changing behaviors), and political (regulations). The types of evidence included: personal experience, beliefs/principles, academic/scientific (generated through class discussions, readings, or instruction). These themes were then matched to the

typology described by Nisbet (2014) only after all of our coding was complete. Our intentions were to remain as unbiased as possible, and we chose not to use Nisbet's framework as a codebook because it was developed using news stories as primary sources of evidence. However, we discovered that it aligned well with our own codes.

To establish trustworthiness of our analyses (semantic and latent coding) two authors read, reread, and coded every essay concurrently. The third author coded half of the essays for the semantic coding. In comparing codes, we were able to maintain high (>90%) inter-rater reliability, and whenever any discrepant codes were identified, essays were re-coded until we came to consensus. Prolonged engagement of our research team over the past decade ensured high inter-rater agreement. Prolonged engagement (over the semester) of each instructor with our respective students enabled us to draw on informal knowledge about students based on field notes regarding class discussions following class.

Findings

Both our semantic and latent analyses revealed that the nature of what students from the two cohorts wrote about differed, as well as the frames they used to construct their arguments. Although almost all of the students presented dialectical arguments with intentions to persuade readers about their decisions (Prelli, 1989), there were patterns across the two cohorts of students that are noteworthy. First, students from the Public University were more likely to draw on academic scientific evidence presented during class or reading material compared to the Tribal College students. Second, although the four frames that students across institutions used were the same as those in the reading assignments, some frames were present in both cohorts, and others were more prevalent in one cohort than the other.

Supporting SSI Arguments

Not all students drew on academic scientific knowledge, although all drew on some type of personal knowledge. Therefore, not all students demonstrated in their writing that they were negotiating different funds of knowledge. Moreover, students from the two cohorts drew on different personal knowledge, and as a result, their claims differed. The arguments in the Tribal College cohort represented all three of the evidence-supported categories (*objective*, *subjective*, and *authentic*), whereas most of the arguments in the university cohort only represented *objective* or *subjective* arguments. More university students (46%) than Tribal College students (30%) wrote arguments coded as *authentic*. Tribal College students (52%) were more likely to write *subjective* arguments compared to the university students (17%). About 30% of both cohorts wrote *objective* arguments. To better understand the types of evidence, we classified the various types of evidence students used as *personal experience*; *beliefs/principles*; and *scientific* (Sadler & Zeidler, 2005). Scientific evidence was almost always related to class discussions and/or readings (Table 1). Using this coding scheme, we found that about half of all students combined (55%) used more than one category of evidence as they developed their argument. The most conspicuous difference between the two cohorts was that 70% of the Tribal College students drew on beliefs or principles as evidence, compared to only 46% of the university students. As Celia (pseudonyms are used throughout), a Tribal College student noted, "*. . .others will have different views depending on what they do, how they grew up and what they value*." This was evident based on the types of supporting examples and rationale used in essays.

The Anishinaabeg believe that the environment is able to resolve its own imbalances if humans allow it to do so (Gross, 2002). This principle was evident in several essays from the Tribal College students.

Table 1
Types of evidence used by students at both institutions to support their claims

Evidence Categories	Example Narratives	Tribal College Students (n = 23)	University Students (n = 24)
Academic scientific knowledge	*Bacteria, in irregularly high numbers, use up most of the oxygen from the floor of the Gulf. This lack of oxygen creates dead zones where the oxygen level falls from the regular 10 ppm to less than 1 ppm, thus making it inhabitable for sea life.*	14 (58%)	23 (96%)
Personal experience	*. . .nitrates are a problem for our lakes in Minnesota. I have been told of a product that is specifically used near lakes. We only fertilized in the backyard and did not in the front yard near the water. Granted all of the back yard fertilizer runs into the lake, but it makes me feel a bit better.*	6 (26%)	18 (78%)
Beliefs/attitudes/values	*How can you take care of yourself and not see what you do to others without thought? I am talking about the land and water and with that the animals and plants that do not have a voice to say that why? Why are you killing me off when you know you need me, that you know that your life will not be balanced if I go?*	16 (70%)	11 (46%)

> *I think that it also shows that any change in an environment, manmade or natural, can have such drastic effect that one might not even think was possible, and may perhaps be almost impossible for anyone to fix except Mother Nature herself in her own due time. (Jennifer)*

> *Nature has its own way of doing things. It has been the same thing for years and years. . .I think most Native Americans think the same as me. Native Americans know that everything comes from Mother Nature, so it should not be messed with. Some other non-native people may think another way. Some people are just raised with different and have different morals. (Ruth)*

Forest, a Tribal College student, believed that trying to control nature is not beneficial: "*To avoid a crisis [man] attempts to control or harness nature, which, in turn, usually causes more damage than good*."

The university students also drew more heavily on personal experiences (78%) than the Tribal College students did (26%). Almost all of the personal experiences upon which the university students drew were related to their lives growing up on a farm or in rural communities. These students wrote about the livelihood of farmers who depend on fertilizers to produce desired profit. In some cases, students discussed hunting on farmland and being sympathetic to the concerns of farmers.

> *As a hunter I like to see wetlands and wildlife areas created for wild game, but I also understand that the cost of running those areas can be expensive and not cost effective. With a demand for food on the rise, farmers have tried to find ways of increasing their yields. (William)*

Other students were brought up on farms or had family members who farmed. The personal experiences of seeing run-off or knowing what the economic costs of not fertilizing are examples of evidence used to support their claims. *"My extended family is all farmers. I have personally seen the effects of runoff into the creek near by the field. It became so filled with fertilizer that my cousins could not swim in it anymore." (Courtney)* and

> *[Farmers] need to make a living and if they were dealing out all this money to help something that probably doesn't affect them then why would they want to do it out of their own pocket and I know this from personal experience growing up on a farm. (Gillian)*

Students from both cohorts used scientific evidence from class discussions or from the readings to support their claims. However, almost twice as many of the university students (96%) used scientific evidence than the Tribal College students (58%). For example, Mandy and Annie, two university students wrote, *"The nutrients mainly come from runoff of farmers. These nutrients fertilize the growth of algae, which goes through its life cycle, dies, and drops to the bottom where they create a massive banquet for the bacteria below." (Mandy)* and, Annie wrote that

> *. . .During these times the lipid content of shrimp is also significantly lower causing valuable shrimp to die off. This also allows for many of the predator fish such as jellyfish to flourish because they feed on the creatures that aren't surviving and the predator population begins to grow.*

Tribal College students also used scientific evidence to support their arguments, as Carol Ann illustrates,

> *If the cold-water stays on the bottom and the warm stays on the top layer then the oxygen or pollutants get trapped in either layer. The mixer of the water on how long it spends in the lake or bay or estuary. The strength and direction of the wind also affects on how many storms that come through fro they also affect the mixer of the water. With poorly mixed water the chances of hypoxia will happen.*

For the most part, when students from either cohort used scientific evidence, they demonstrated understanding of the scientific concepts.

Framing SSI Arguments

Some claims were presented as problems, which we categorized. We examined the types of claims that were solutions (often decisions about behaviors) to the problems described. In total, 46/47 of the students identified claims in their essay sets and all of these were also classified as dilemmas, that is, descriptions that a solution was needed but might be difficult to achieve (Table 2). Despite some overlapping frames (*accountability* and *compromise*), the singular frame of *economic development* was prevalent only in university student essays and the singular frame of *morality* was prevalent only in Tribal College student essays. Some university students combined the frame of *economic development* with *morality*, but none of the Tribal College students used the *economic development* frame (Figure 2).

Accountability. Often, students made claims that others should change their behaviors or ways in order to resolve the issue. Accountability for actions was the most commonly overlapping frame used in both cohorts. Most often, students from both cohorts offered solutions that farmers should reduce their fertilizer use (56% of tribal students and 58% of the university students), but the students from the university added that the farmers can only do this if they were financially

Table 2
The frames that college students used in SSI arguments regarding coastal dead zones implicated by nitrogen pollution in rivers

Frame	Theme	Example Narrative	Tribal College Students (n = 23)	University Students (n = 24)	Overall Students (n = 47)
Accountability	Culture is difficult to change; it requires time, effort, and money	*People [here] look at this as not our problem. . .this is a dilemma that has occurred so many times over the entire time people have been on this earth. . . . it is everyone's problem. . .but, generational habits are even harder to break*	13 (56%)	14 (58%)	27 (57%)
Economic development	Economic dilemma (economic livelihood is more important than environment)	*Fertilizer is a big deal with those farmers. . .they shouldn't have to pay for these huge systems [controlled drainage] out of nowhere. They don't have the money to be able to do this.*	1 (4%)	17 (71%)	18 (38%)
Morality	Environmental dilemma (we are responsible for our actions in our environment)	*The fish shouldn't have to move, being they were here first; we as people should grow and have enough thought to leave the water alone, give time for life to grow back.*	16 (70%)	2 (8%)	18 (38%)
Compromise	Both economics and environment are important; find middle ground	*If we could come together to make both sides meet their needs, maybe we could as people overcome the pollution that we are putting in our waters.*	6 (26%)	6 (25%)	12 (26%)

Most students used more than one frame within their argument.

compensated by the government to do so. An unusual claim was made by one Native student (Wes), who suggested that farmers "*be removed and relocated to areas without a water source. . .*" This suggestion caught our attention considering that many Native people in the United States were historically removed and relocated to reservations. Even today, the Anishinaabeg recount stories of how their grandparents were forcibly removed from their families and placed in boarding schools intended to "Anglicize" them. Although students from both cohorts offered solutions, there were also students who recognized that changing cultural practices is difficult (35% Tribal College students and 2% University students). Other students explained that although change is needed, it might not occur because it requires time, effort, and money (22% Tribal College students and 42% University students). Michelle, a Tribal College student, explained that people should take ownership of their problems. "*People [here] look at this as not our problem. . .this is a dilemma that has occurred so many times over the entire time people have been on this earth. Out*

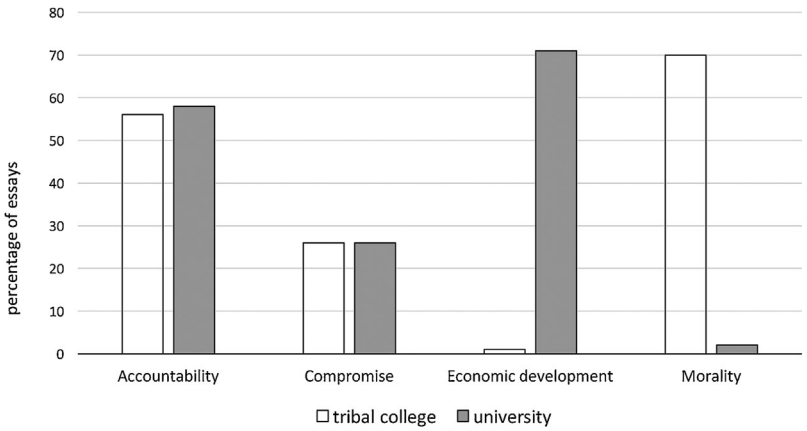

Figure 2. Percentage of student essays using one of four frames in arguments about resolving an environmental socioscientific issue. Although accountability and compromise were frames equally represented at the two institutions (Tribal College and State University), economic development and morality were not.

of sight out of mind is a saying that comes to mind. . . it is everyone's problem. . .but, generational habits are even harder to break." On the flip side, a University student, Victoria, felt that some people should not be accused as the problem-makers. "*Farmers get blamed for everything and are an easy target. . .after all, [farmers] have been doing this for centuries, so why make them change now?*"

Economic Development. In contrast, the university students, more often than the Tribal College students, used an *economic development* frame. They argued that farmers faced greater economic hardships than fisherman downstream because farmers relied on fertilizer use to increase agricultural yield. Interestingly, some university students dismissed the Gulf of Mexico fishermen as hobbyists and not professional fisherman who rely on high yields to make a living. University students, nonetheless, wrote solely or more heavily about economic issues, such as loss of income for farmers and/or fishermen (71%; 17/24) compared to the Tribal College students (4%; 1/23). Victoria, a University student, wrote, "*I come from a family of farmers and I know how hard it would be if they didn't have their fertilizer to grow that years' crop. Fertilizer is a big deal with those farmers. . .they shouldn't have to pay for these huge systems [controlled drainage] out of nowhere. They don't have the money to be able to do this.*" William explained that ". . .*farmers have had to take extra steps in order to fulfill the need. Fertilizers and utilizing every acre of farmable land are just a few ways farmers have tried to expand their profits and help aid in the demand for small grains.*"

Morality. The two cohorts displayed differences in how they framed their claims. Seventy percent (16/23) of Tribal College students used a *morality* frame and wrote about people's moral responsibility to consider environmental consequences of pollution over economic consequences, whereas only 8% of University students (2/24) felt this way. Using the morality frame, the Tribal College students more often wrote about the negative consequences of fertilizer run-off on the ecosystem, whether they included the effect on humans or not. For example, Wes, a Tribal College student, wrote, "*The fish shouldn't have to move, being they were here first; we as people should grow and have enough thought to leave the water alone, give time for life to grow back.*" One Tribal College student, Carol Ann, argued that change in behavior may not occur, not just because of financial reasons but because of dispositions and attitudes toward natural resources. In her

morality-framed argument, she wrote, "*. . .time is the only thing that can heal the land completely. The land was not made for farming. It was once a forest full of trees. That is what is should have been today. . .If there is greed out there and as well as egos that go on forever, then you will see these problems again, not just for the money they will be getting from these deals [farming choices] but from the chance that they can play god*."

Compromise. Dilemmas were identified when students explicitly recognized that actions had two different, often competing interests and consequences. Each cohort had students who expressed arguments that centered on both economic and ecological concerns (26% of the Tribal College students and 25% of the University students). These students wrote about finding compromises between two competing interests (environmental balance and farmers' economic stability). "*I think it would be important to help farmers with the run off from fertilizers and also let everyone know about the importance of a healthy ecosystem"* (University student, *Marianne*). Lara, a Tribal College student, proposed, "*if we could come together to make both sides meet their needs, maybe we could as people overcome the pollution that we are putting in our waters*." It was more common for the Tribal College students to discuss collaborative efforts to resolve the issue (61%) compared to the university students (17%). Some students from each cohort made decisions about personal behaviors. "*This problem seems far removed for us in the Northland. However, the nitrates are a problem for our lakes in Minnesota. The nitrates from the fertilizer encourage the growth of a form of milfoil [a weed]. This is how I compromised and addressed the dilemma in our yard. We only fertilized in the backyard and didn't in the front near the water. Granted all the backyard fertilizer runs into the lake, but it makes me feel a bit a better.*" (University student, *Noelle).*

Discussion

The research objective of this study was to evaluate the types of frames that college students employed in written dialectical arguments about an environmental SSI. In our effort to increase scientific literacy (the ability to use scientific knowledge to make and articulate decisions), we assigned argumentative writing tasks around an SSI that was both locally and globally relevant to our participants. In our effort to be culturally sensitive, we did not prompt participants to adopt a particular frame, and we refrained from sharing our positions. We designed writing prompts to be sensitive to multiple interpretations for solving the problem and, as anticipated, we observed the use of different frames across the two study sites. All students received the same academic scientific information through reading and class lectures/discussions, but a finding we did not anticipate was that the use of different frames was associated with varying use of academic scientific evidence. The Tribal College students, who were more likely to use morality frames, were almost half as likely to use academic scientific evidence to support their claims. These findings beg the question of how trade-offs between increasing academic scientific content knowledge and allowing students to select their own frame for argumentation tasks can be managed through writing prompts.

The most common frame used in University essays was *economic development*, whereas in Tribal College essays it was *morality.* The University students, who came from predominantly agricultural or rural backgrounds, framed their arguments using economic development claims. Even University students who advocated for *compromise*, still argued that fertilizer use was important economically. Only a single student mentioned that the fishermen in the Gulf suffered economic losses. This indicates that the students were unable to describe environmental and economic systems beyond their local context, as Kolstø (2006) reported in his study of Norwegian students studying power lines and the perceived risk to children's health. Conversely, the Tribal

College students were more likely to make claims that valued the environment at the expense of economic concerns. We were not surprised to discover that the Anishinaabeg students strongly valued the environment and ethically considered it "the commons." The Tribal College goes to great lengths to support the teaching of science and mathematics while valuing students' TEK. The Tribal College relies on both permanent teaching staff and adjuncts to teach their science courses. Students are encouraged to integrate their personal experiences and TEK with formal science knowledge that is introduced in the courses, as this has been found to encourage students to maintain both their cultural heritage and an interest in studying science and mathematics (SD, Personal Observations). Unlike at the university, though, the Tribal College instructors (permanent faculty and adjuncts) do not regularly meet to ensure curriculum articulation and to discuss what academic science content should be taught in each course. The fact that students may not be exposed to some academic science content across courses may be one explanation for the lower use of such evidence in Tribal College essays.

In their essays, Tribal College students felt passionate about people's responsibility toward the earth and allowing "Mother Nature" to "recover" from pollution. Cajete (2000) described that community-developed solutions are a part of Native cultures and worldview, and several Tribal College essays indeed supported this notion, as Lara described. Several Tribal College students suggested that farmers should stop fertilizing altogether for a period of time until the aquatic ecosystem can recover, using an *accountability* frame. Some farmers may argue that this is a naïve solution; however, we believe that Tribal College students were negotiating a belief that people must be ecologically sensitive if farmers want economic yields in the long term.

The University students were almost twice as likely (96%) to draw on academic science evidence as their Tribal College student peers. Snively and Corsiglia (2000), however, challenge the science education community to question what science is, and in this vein, we interpret our findings with caution and urge readers to do the same. In our analysis we only coded narratives as academic science if the concepts were explicitly discussed during class discussions with the instructor or in the readings; however, some might argue that evidence used by some students does, in fact, "count" as science from a TEK lens. For example, several Tribal College students alluded to the construct of sustainability, even though they did not explicitly refer to concepts discussed in class. Carol Ann lamented that, "*the land was not made for farming. It was once full of trees*." And Wes suggested that farmer should "*be removed and relocated to areas without a water source.*" Both of these students alluded to the ecological constructs of *constancy* (ability of systems to resist change) and *resilience* (ability of systems to return to original states after disturbance) (Ricklefs, 2010). Although the construct of resilience assumes that systems have mechanisms to recover from disturbances, both Carol Ann and Wes implied that people, who have been the source of disturbance, have the power to control their behaviors. In other words, they view humans as part of the system and not separate (Casper, Balgopal, & Fernández-Giménez, 2016; Orr, 1992). Making decisions about environmental disturbances can be complicated when they involve multiple consequences, such as economic, social, and political, in additional to ecological ones (Patronis et al., 1999). For an individual to make a decision requires him/her to determine what the trade-offs of each potential claim are and to justify why this decision outweighs other options. Furthermore, it is particularly challenging to simply categorize evidence as scientific or not (Cajete, 2000; Snively & Corsiglia, 2000), especially if indigenous people do not identify their own knowledge as science (Ogawa, 1989).

Because our iterative writing tasks supported students to draw on their own funds of knowledge as evidence and was not prescriptive about the types of claims and frames we expected students to use, we tentatively believe that some participants entered their respective hybrid spaces. Although we did not interview students for this study, we infer from student writing in both

contexts that, when they used combinations of academic science knowledge (based on class discussions and readings), personal knowledge (often prefaced with specific background content; "on my grandpa's farm. . ."), and beliefs (either indicated by declarations of "I believe" or supported by moral or ethical justifications and imperatives), they were exploring how to integrate their funds of knowledge or life worlds (Calabrese Barton et al., 2008). It is known that socio-cultural and economic factors influence how people frame their understanding of climate change (Anderson, 2009); likewise, we anticipated that other environmental issues (including aquatic hypoxia and agriculture) are likely understood and communicated differently based on people's worldviews. For college students this means that they must negotiate what perspectives and knowledge they bring from their previous education and personal lives to the academic world, where they are exposed to WMS.

When students draw from both funds of knowledge to support claims using a focused frame, we inferred that they were finding a third space—one that legitimized both worldviews and ways of knowing (personal and academic). We posit that some Tribal College students were finding a third space—where they could frame their SSI solution using a morality frame, which is supported in their academic context. The trade-off may be that only half of these students (58%) integrated academic science content as support even when presented with the same content background in readings (Table 1). Likewise, some University students may have been navigating a third space when they drew on personal experiences (78%) to support academic science knowledge (96%) as evidence (Table 1). Not all students drew on both sources of evidence, but for those who did, we posit, were defining a hybrid space that bridges both their personal and academic worlds. Moreover, drawing on personal knowledge of the farming community likely influenced the economic development frame that many (71%) University students used (Table 2).

Some students had to compromise little; however, for others, the differing views likely required more thoughtful consideration of how to find a middle path. In our subsequent studies, we are using formal interviews to further explore this and recognize that then only can we make more definitive claims (Unpublished Data).

As students make decisions about dilemmas, they draw on many types of evidence, including common sense, personal experiences, and classroom experiences, using informal reasoning to respond to new information and to develop their positions on scientific issues which are of societal concern and do not have a clear cut solution (Sadler, 2004). Decision making about an environmental SSI, in that regard, often involves emotions and moral reasoning, as we and others have also found (Sadler & Zeidler, 2005; Zohar & Nemet, 2002). Informal reasoning allows an individual to make sense of an open-ended issue for which there may be multiple perspectives and for which the individual may draw upon multiple sources of information (Kolstø, 2006), including personal beliefs and worldviews. Our educational system is built on assumptions of what science is, and even if educators and scientists adopt a broader view of what "counts as science," we contend that it is empowering and essential for marginalized students to be well-versed in WMS as well as their own ways of knowing (which may include TEK). Although they argue that marginalized voices should be legitimized, Kincheloe and Steinberg (2008) are cautious about the construct of hybridity, which they argue, implies binary epistemes. We agree with Kincheloe and Steinberg (2008) that teachers should give students the chance to study "disciplinary knowledge from as many frames of reference as possible" enabling them to gain multilogical insights (p. 139). Yet, we adhere to the description of Calabrese Barton et al. (2008) that recognizes that students may blend various life worlds, a framework that is not restricted to a binary TEK versus WMS system.

Bang and Medin (2010), as well, argued that students can adopt multidimensional epistemologies and negotiate "different orientations" in different contexts. They call for science educators to include indigenous voices in designing curriculum to accommodate Native

epistemologies without compromising instruction of Western ways of knowing the natural world. WTL models that explicitly encourage students to draw on and negotiate different types of evidence, we believe, supports both the blended life world and multidimensional epistemology frameworks (Figure 1). The next step in the development of these curricula would be to include opportunities for students to engage in a metacognitive awareness of their own epistemological orientations that influence their decision-making, and a recognition of how these interact with WMS. For example, according to Fan Shen (1989), once he realized that his Chinese worldview of *yijing*, creating mental images to "reach a unity of nature, author, and the reader" (p. 464), was contradictory to the worldview of his professors, who held Western notions of what a logical argument is (which included the "use of a topic sentence," p. 462), he went through "a process of creating and defining a new identity and balancing it with the old identity" (p. 466). By being metacognitive, Shen (1989) was able to adopt and adapt his writing identity ("I imagine myself slipping into a new skin," p. 465) so he could best express himself to different audiences. We believe instructors should encourage students to be reflective of their ways of knowing and reasoning throughout a course, so they can define their own identities as science learners and communicators.

Informal (intuitive and emotive) reasoning is influenced by individuals' value and belief systems (Grace & Ratcliffe, 2002), as well as by their ability to weigh information from many sides (Kolstø, 2006). Jimenez-Alexeixandre and Pereiro-Munoz (2002) found that 11th grade students often placed higher value on ecological concerns over economic ones, in part, it was suggested because of their potential lack of understanding of economic systems. The authors suggested that it should not be expected that informed citizens possess all knowledge about an ecological issue in order to participate in decision-making processes because people take different positions based on their own life experiences. In this regard, perspectives will undoubtedly vary based on life experiences and worldviews. Sadler and Zeidler (2005) proposed that educators study opportunities in the classroom that allow students to "explore their own informal reasoning without prescribing a particular mode of reasoning (p. 130)." We extend this proposition and argue that educators should explore their own and students' assumptions about what is science and what "counts" as evidence, especially if they encourage students to frame SSI arguments in personally meaningful ways.

When SSIs require communities to make choices that consider economic, environmental, and cultural considerations, emotions can be strong. Out-of-school identities may be evoked as students consider socially important scientific issues. For example, Evagorou et al. (2011) found that Asian-British students constructed different claims about how to manage introduced squirrel populations compared to domestic White British students, who were not as sympathetic. The Asian-British students, on the other hand, identified with the introduced squirrel arguing that the new comers have rights too. Though this observation was not further probed by the authors, what was reported in their study supports the fact that students from different cultural worldviews may examine problems in different ways, and in the process, propose different solutions (Goffman, 1974). The immigrant and minority students constructed frames grounded in *morality*; whereas, the White students framed their arguments around environmental *accountability* frames. Because different frames may logically require different types of evidence as support, some students may be trying to make meaning of academic science content in different ways than others.

Implications

Although "natural frameworks" may be more likely to be shared by people, "social frameworks" involve rules, which may be interpreted differently without clarity, according to Goffman (1974; p. 24). Frame analysis may center on either *frames in thought* (during dynamic interactions) or *frames in communication* (in static text), yet both are windows into the reasoning and meaning-making process students to bring to discourse spaces (Davis & Russ, 2015;

Druckman, 2001). The dilemma for the educators is to empower students to select their own frames and draw on both academic and personal funds of knowledge, without compromising opportunities to increase science content knowledge. WTL instructional strategies, when designed with specific prompts that encourage students to draw on multiple types of evidence around locally and/or culturally relevant issues do not have to compromise students' use of academic science content (Balgopal, Casper, Wallace, Laybourn, & Brisch, 2015). WTL activities allow students the chance to be deliberate in their choice of evidence, as they can see their thoughts on paper, unlike oral arguments (Bereiter & Scardamalia, 1987). Based on our current studies for which students wrote about cell biology and cancer treatments, all of our participants drew on academic science to support their claims, and many blended their sources of evidence (Balgopal et al., 2015). By guiding students to consider what claims they want to make about local environmental SSIs and about potential solutions to resolve these issues, along with discussions about what types of evidence are most meaningful in supporting their particular claims, we can help students become more thoughtful about their arguments and the frames that they choose to use. We encourage educators to consider (i) using written discourse to assess argumentation and reasoning; (ii) drawing on locally relevant issues as prompts to engage all learners; (iii) reconceptualizing what "counts" as *science*; and (iv) allowing students to frame their arguments in ways that are meaningful to them.

First, writing allows students to not only examine their choice of evidence and reasoning but to have each voice heard (unlike small group discussions in which some students remain silent). In writing assignments, as with any instructional and assessment strategy, educators must recognize that students bring varying worldviews to the science classroom, so we must help students evaluate what evidence they believe best supports a claim (Kelly, Regev, & Prothero, 2007). Because there are multitude of ways that diverse writing activities can be integrated into curricula, it is necessary to be cognizant of local and educational contexts (Kelly & Bazerman, 2003). Second, we believe that examinations of locally relevant issues may allow students to draw on multiple data sources since they are more likely to have encountered or thought about the issue outside of school (Sadler, 2004). If students feel too removed from an issue, they will invest little emotional energy in trying to find solutions to resolve the issue. Extending this claim, we argue for educational contexts to include allowances for students' cultural funds of knowledge. That is, students need the opportunity to enter hybrid spaces when making meaning of academic science. We argue that a comparative study such as ours is valuable, if we are to implement curricula and instructional strategies that are culturally sensitive and thoughtful in promoting informed decision-making skills across educational and cultural contexts. Furthermore, the construct of hybrid space warrants further examination in SSI studies. Third, our study requires researchers to question our own constructs of "science" and "personal funds of knowledge." We join other scholars in asking our colleagues to question what knowledge is legitimized as science (Cajete, 2008; Endres, 2014; Kincheloe & Steinberg, 2008).

Finally, we recognize the limitations of academic science when Tribal College students described natural phenomena in ways other than used during instructor-guided discourse. We implore our colleagues, therefore, to not use an overly restrictive definition of academic science in order to be sensitive to other ways of knowing (Mueller & Tippins, 2010). When Forest, a Tribal College student, described how people try to "*control or harness nature, which, in turn, causes more damage than good*" he expressed a claim that is rooted in his belief system. Were he not able to be candid about his beliefs/morals, constructing an argument around solutions to an environmental SSI may not have allowed him to negotiate meaning in an academic science class. By allowing students to tap into their personal experiences and informal knowledge, educators can legitimize other funds of knowledge, especially if it allows students to make meaning of sometimes complex, natural phenomena or to adopt argumentation frames that are contrary to the teacher's frame. We do

not argue that instructors should encourage indigenous students to reject WMS because we do not believe that learning about the natural world happens in an "either/or" model. We simply suggest that science instructors be sensitive to the value of multiple ways of knowing that all of our students bring to the classrooms as well as encourage students to acknowledge this.

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