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Developing socioscientific perspective taking

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ABSTRACT

Perspective taking has been identified as a critical skill in the development of scientifically literate citizenry. Despite the importance of the construct, operationalising and identifying effective pedagogical strategies to promote effective perspective taking have proven challenging. This study provides empirical evidence to support the theoretical Humanities, Arts, and Social Sciences model for identifying effective perspective taking interventions in the science classroom. A modified perspective reading and writing intervention was imbedded within a postsecondary environmental science course examining the management of wolves in North America. Participants demonstrated more nuanced abilities to consider various perspectives and **identify** the complexity of managing wolves in Northern California.

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Introduction

Historically, science education has overemphasised scientific content knowledge and neglected the sociocultural aspects of learning science (Sadler & Zeidler, 2009). Over the last decade, creating an informed-citizenry capable of negotiating complex issues has become a priority for science educators internationally (Roberts & Bybee, 2014; Zeidler et al., 2019). The shift in science education goals demonstrates a desire to move toward a type of scientific literacy with less emphasis on the memorisation of decontextualised scientific facts and more of focus on contextualised scientific knowledge to resolve complex and ill-structured socioscientific issues (SSI) (Zeidler et al., 2005). One critical skill for meaningful participation and eventual resolution of SSI is the ability to consider multiple perspectives related to a given issue. While perspective taking may also be thought of as a precursor, and at the same time, a catalyst to the development of empathy, there is little in the science education literature that identifies effective interventions for promoting perspective taking (Kahn & Zeidler, 2019). Kahn and Zeidler (2016) have advocated for a Humanities, Arts, and Social Sciences (HARTSS) model (described in detail below) where effective perspective taking interventions from other academic disciplines are embedded within a SSI framework. While elements of that model have been examined in prior

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research (see Kahn & Zeidler, 2016, 2019; Owens et al., 2019), at this point, there has been no empirical research examining the effectiveness of key elements of the HARTSS model in concert with one another. To that end, the overarching purpose of the present study aims to examine empirical evidence that may support its use, and help to inform pedagogical practices within a SSI experience.

When designing SSI experiences, it is particularly important to select issues that are relevant and compelling to students. This allows students to negotiate the complex sociocultural aspects of the given issue, which, in turn, provide experiences that foster the skills necessary to participate in the resolution of the issue (Presley et al., 2013; Sadler, 2011). In keeping with the recommendations in the literature, wolf management in North America in general, and the U. S. state of California in particular, was selected as the compelling issue for the SSI unit for this study. As with other parts of the western United States, wolves returning to California continues to be a contentious issue impacting a multitude of citizens of diverse backgrounds who reside in this area. Accordingly, three research questions were addressed in this study:

- (1) To what extent, if any, do students identify shifts in their socioscientific perspective taking (SSPT)?
- (2) What aspects of the SSI experience influenced students' ability to consider various perspectives related to wolf management that incorporated perspective-taking interventions?
- (3) In what ways might students' understanding of wolf management be impacted as a result of engaging in an SSI experience that incorporates a perspective reading/writing intervention?

The international prioritisation on creating a scientifically literate society is the underlying motivation for these research questions (Åkerblom & Lindahl, 2017; NGSSLead States, 2013; UNESCO, 2019). Prior studies have identified perspective taking as a crucial component for the development of functional scientific literacy (Kahn & Zeidler, 2016; Zeidler et al., 2019). To this end, facilitating the consideration of various perspectives has shown to be difficult, especially when the values and priorities of different perspectives oppose the values and priorities of the individual (Sadler et al., 2007). This study seeks to identify a specific intervention for perspective taking that can be embedded with a SSI curriculum.

Literature review and theoretical framework

Introduction

Perspective taking has been studied extensively throughout educational research. For example, Roan and colleagues (2009) discuss perspective taking as a skill influenced by cognitive, emotional, and motivational factors in an attempt to determine the thoughts, feelings, and perceptions of another person. Kahn and Zeidler (2016) operationalise perspective taking more generally as, 'one's ability to recognize and consider the diverse cognitive and emotional viewpoints of others,' (p. 263). Both iterations point to the complex and multidimensional characteristics of perspective taking. Despite the complex nature of

perspective taking, the interpersonal techniques necessary for effective perspective taking (i.e. communication skills, hypothesising skills, awareness of bias) can be modified and trained (Roan et al., 2009).

The ability to consider multiple perspectives is vital to developing functional scientific literacy, promoting engagement in SSI, and facilitating moral decision making (Kahn & Zeidler, 2019; Sadler et al., 2007; Zeidler et al., 2005). For example, perspective taking has been demonstrated to be a vital component of the development of empathy. Lamm et al. (2007) assessed university students watching videos of patients being exposed to painful noise as part of a fictitious medical treatment. The students were asked to either imagine how they would feel if they were the patient or tried to identify with how the patient in the video felt. The authors found a certain degree of cognitive capacity was necessary for effective perspective taking. Research participants were able to regulate their emotional responses to the patients' pain when the participants thought the perceived treatment had long-term positive results. These results support the notion that individuals must first, effectively recognise others' perspectives, but also be cognisant that any emotions the observer feels are in response to the emotions of the observed. Thus, the ability to weigh evidence in an effort to regulate emotional responses to situations is critical for individuals to make decisions on contentious issues.

Additionally, research in place-based environmental education using a SSI approach determined that perspective taking plays a vital role in the use of emotive reasoning and the development of empathy. Herman et al. (2018) examined the extent to which undergraduate students who participated in a SSI-embedded course in a National Park expressed emotive reasoning toward people and nature impacted by contentious environmental issues. It was found that the catalyst for students' ability in expressing emotive reasoning was their ability to consider the perspectives of individuals (anthropocentric empathy) and natural entities (ecocentric empathy) impacted by the issue.

This shift in emphasis towards functional scientific literacy is related to research revealing that improved perspective-taking is also linked to improved leadership, moral development problem solving, complex judgement, and critical thinking (Avolio, 2010; Gehlbach, 2004; Hoffman, 2000; Kohlberg, 1969). Despite the documented impacts of improved perspective taking, little is known about how to develop the requisite skills in science classroom settings. However, it has also been noted that developing perspective taking can be difficult because students often resist considering perspectives that deviate from their own (Sadler et al., 2007). This type of 'make-sense epistemology' is similar to how individuals allow ideas that align with core beliefs to become a part of their knowledge base while dismissing or ignoring evidence to the contrary (Zeidler et al., 2003).

Drawing on conceptual and analytic arguments, Kahn and Zeidler (2016, 2019) propose that implementing perspective-taking interventions from academic disciplines outside science education may be a productive approach for fostering perspective-taking in the science classrooms because individuals tend not to use a single strategy; rather, students tend to select strategies that better align with their preferred modes of communication. As a case in point, Gehlbach and Brinkworth (2012) studied 18 adults and 13 high school students diagnosed on the Autism Spectrum to determine what strategies they implemented when considering other perspectives. The participants were asked to reflect on previous experiences and take the perspective of two individuals in a video. The authors identified 12 unique strategies used by the participants. While Gehlbach and

Brinkworth were able to identify strategies that individuals used to consider other perspectives, they did not identify how these strategies were developed by the participants or the extent to which specific pedagogical interventions were implemented to facilitate the strategies.

This gap in the literature is evident elsewhere. For example, Johnson (2015) examined perspective taking while discussing sociocultural issues in college classes. A key finding from that study was the need for educators to explicitly help students negotiate discussions on sociocultural issues; however, the author stopped short of recommending specific pedagogical strategies to accomplish effective perspective taking. Additionally, while other authors recommended that students' exposure to less widely held perspectives toward sociocultural issues should be embedded within their educational experiences, empirically effective approaches to accomplish this remain unidentified (Dey et al., 2010).

Socioscientific issues framework

The Socioscientific Issues Framework (SSI) offers a sociocultural approach to the development of functional scientific literacy, which draws from the intersection of science, culture and character (Zeidler, 2014; Zeidler et al., 2005; Zeidler et al., 2014). In doing so, this framework intentionally attends to the kinds of normative factors, such as moral motivations, personal values, ethic of care, or other social milieu, that are often overlooked in more traditional approaches to science teaching which tend to privilege scientific reasoning devoid of such contextualised considerations. Instead of only providing a context for science content or simply pointing out ethical dilemmas, SSI instruction uses a well-designed theoretical framework to capitalise on the pedagogical power of controversial issues to stimulate emotional growth, as well as moral and ethical development (Sadler et al., 2007; Zeidler et al., 2005; Zeidler & Kahn, 2014). When SSI is well designed, students can address content knowledge, nature of science, and epistemological reasoning while investigating contentious issues (Fowler et al., 2009) through discourse, research, and critical analysis of the problem (Zeidler & Kahn, 2014). This process simulates both how scientific inquiry is conducted and provides opportunities to develop the skills necessary to become a scientifically literate contributor to society.

SSI instruction is situated within relevant, often ill structured, real-world scientific contexts understandable to students through pedagogical facilitation of key strategies from the teacher (Zeidler et al., 2011; Zeidler & Kahn, 2014). SSI instruction includes confronting students with personally meaningful contentious issues and helping them to develop and contemplate multiple sophisticated viewpoints while weighing scientific evidence. Concurrently, students must evaluate normative factors associated with the issue including the social, moral, and ethical implications associated with proposed solutions (Zeidler et al., 2005). Furthermore, students argue, discuss and debate while justifying their reasoning and decision-making regarding the SSI. The proper immersion into a SSI can generate cognitive and moral dissonance as students consider their existing views side-by-side with the perspectives of others regarding those issues (Fowler et al., 2009). To resolve these internal conflicts, students must think reflexively and consider their biases, misconceptions, and emotions. As students engage in the contentious issues, they develop a deeper understanding of the science content, as well as effective communication skills through collaborative problem solving, discussion, and debate (Kahn & Zeidler, 2016).

Central to implementing SSI is understanding the pedagogical importance of cultivating a construct referred to as socioscientific reasoning (SSR) (Sadler et al., 2007). It is a construct embedded within the SSI framework that identifies and addresses key cognitive skills necessary to negotiate a SSI. SSR consists of five components:

- Complexity: the ability to perceive and reason through the complexity inherent to SSIs.
- Inquiry: the ability to recognise information that is not available regarding an issue as well as the ability to consider ways in which that information may be generated.
- Perspective-taking: the ability to analyse an issue and potential solutions from the perspectives of different stakeholders.
- Skepticism: the ability to identify potential sources of bias that may influence information or the presentation of information about an issue or potential solutions.
- Affordances & Limitations of Science: the ability to determine how scientific knowledge and processes may contribute to the resolution of an SSI and to recognise dimensions of the issue that cannot be addressed by science (Zeidler et al., 2019).

Students' SSR skills are vital to their ability to navigate SSI, as well as act as scientifically/environmentally literate citizens in the context of investigating contentious environmental issues (Herman et al., 2018).

Humanities, Arts, Social Sciences (HARTSS) Model. In response to Sadler et al.'s (2007) identifying difficulties in promoting perspective taking, Kahn and Zeidler (2016) have suggested transferring perspective-taking interventions shown to be successful in other disciplines to science education. Accordingly, they have advanced a theoretical pedagogical model referred to as HARTSS, which calls for science educators to examine research from other academic disciplines, select interventions that promote perspective taking, embed those interventions into SSI contexts, and validate and empirically test the interventions in science education contexts. It is important to understand that both the SSI framework and the HARTSS model are aligned with a progressive tradition that views social justice and personal responsibility as forms of personal intelligence and worthy of nurturing as an educational goal (Serpell, 2011). However, these forms of intelligence require, at the very least, the formation of an ethic of caring that is necessarily linked to perspective taking.

Kahn and Zeidler (2016) draw on the work of Selman (1971, 1977), Kohlberg (1968), Martin et al. (2008), among other researches, to foster the coordination of social perspectives and dialogical engagement to arrive at decisions related to SSI. Thus, under the HARTSS model, the justification of moral actions is derived from the ability to 'see' and 'feel' the perspectives of others from discussion, rhetoric and argument connected to the normativity of different values. These values are subsequently intricately connected to the perspectives of those that hold them as core beliefs. Accordingly, the authors identify three potential interventions from various academic fields that they propose could be effective, on logical and conceptual grounds, at promoting perspective taking.

To better understand the terrain of how perspective taking is situated within the SSI framework, Kahn and Zeidler (2019) provided an extensive conceptual analysis of Socioscientific Perspective Taking (SSPT) to move toward a more robust model of the construct. This has both important conceptual as well as pedagogical implications. The authors stress that within SSPT, it is important to differentiate among having a position (where one stands on an issue), orientation (how one approaches an issue in relation to others),

and perspective (how one perceives and interprets an issue). Within the process of differentiation, a student is required not only to acknowledge what their perspective is but provide a rationale for why that perspective is held. Kahn and Zeidler further note that,

the term “taking” essentially renders the term ‘perspective taking’ a ‘dead metaphor’ ... for there is no actual ‘taking’ of another’s perspective. Instead, this compound verbiage is necessary to overcome the assumption of “givingness” that undergirds perspective; in other words, “taking” is added to emphasize a shift from the default value that we give, rather than take our perspective on issues ... (p. 627).

Kahn and Zeidler analytically derived the necessary and sufficient conditions for the full expression of SSPT and included three main features: (1) Engagement; (2) Etic/Emic Shifts; and, (3) Moral Context. Thus, any reasonable implementation of SSPT requires attention to the extent that students are authentically engaged in the issues at hand, their ability to shift back and forth between an insiders’ and outsiders’ perspective about those issues and traverse the moral domain of those issues. This latter point is particularly central to the present study in that it implies an educational mandate for those who develop curricula and teach in an SSI framework to recognise the value and necessity of moral development in forming scientific identities (Sadler, 2009).

Of particular interest for the current study is Perspective Reading and Writing, which is used frequently in Language Arts education. This intervention requires students to analyse readings and formulate their own writings from perspectives other than their own. While this intervention has been empirically supported in the Language Arts education literature (LaRusso et al., 2016), it has not been examined in science education proper, or in socio-cultural contexts within science education (i.e. SSI) in particular. LaRusso and colleagues examined the extent to which 2,933 grade 4–7 students’ ability to articulate the thoughts, feelings, and positions of individuals in written scenarios were related to students’ reading comprehension. The study found that a relationship existed between the ability to articulate the feelings of actors in the scenarios, their position in the scenario, and the students’ reading comprehension.

Design and methods

Participants

This study was conducted as part of an undergraduate environmental science course explicitly designed for future K-8 teachers. As such, the participants were part of an intact class with students from a rural university in Northern California examining the issue of grey wolves returning to Northern California. The participants were 33 students, 23 who identified as female and 10 who identified as male and were in at least their third year of post-secondary education. Two majors were represented in the course: 29 students were preparing to become elementary school teachers and four were preparing to become middle school science teachers.

Instructional context

The purpose of the course was two-fold: (1) to develop environmental science content knowledge aligned with the Next Generation Science Standards (NGSS) (NGSS Lead

States, 2013); and (2) to develop educational research and research-based pedagogical practices. Accordingly, students were introduced to Constructivist and Developmental Learning Theory, the Learning Cycle, and the Socioscientific Issues Framework within the context of the environmental science content in order to develop a foundational understanding of the science education literature on these topics. The course met for five hours a week, with four hours dedicated to laboratory investigations and one hour for lecture. A SSI approach examining wolf management in Northern California was embedded within the ecology unit, which was the first unit of the semester and spanned five weeks of a 15-week course. Environmental themes connected to the SSI were emphasised throughout the course.

Pedagogical decisions made in the ecology unit design were consistent with SSI research (Owens et al., 2017; Presley et al., 2013; Zeidler & Newton, 2017). For example, the decisions guiding instructional topics and perspectives were consistent with an eco-justice orientation to SSI (Zeidler & Newton, 2017) that have been found to reveal the central role of emotive reasoning in place-based science education (Herman et al., 2018). Hence, the issue of wolf management was introduced as the topic of investigation at the onset of the unit, learning experiences were scaffolded for higher-order practices, and a culminating experience occurred in the form of townhall-style discussion. The wolf management topic has been found to be a useful SSI topic in other research outside the US. For example, in Sweden, work has been done using this same topic because of its importance in providing an authentic context both for students as well as the stakeholders involved (Åkerblom & Lindahl, 2017; Lindahl et al., 2019). Accordingly, guest speakers with first-hand experience related to this SSI and local media reports were used to emphasise the close proximity of the issue and generate the 'real world' connection. Scaffolded within the SSI experience were laboratory activities designed to introduce the scientific concepts necessary to make informed decisions on wolf management. At the onset, participants were assigned a perspective from which to examine wolf management. Throughout the unit, participants analysed data from their assigned perspective to create a suggested management plan to be presented as part of the culminating town hall discussion.

When selecting learning experiences, a concerted effort was made to orchestrate key elements of the HARTSS mode within the SSI I by imbedding a perspective reading and writing pedagogical strategy, which has been demonstrated as effective in Language Arts education (Kahn & Zeidler, 2016). More specifically, in the context of the present study, perspective reading and writing was used in a manner that required an individual to examine a given text from another's perspective and respond to the text from that perspective, rather than respond from their own perspective. Participants were assigned readings related to wolf management written by various stakeholders and expected to examine the claims and evidence through their assigned perspective, which included livestock ranchers, environmental advocates, indigenous people, eco-tourism businesspeople, hunter/sportsmen, and ecologists. Based on the readings and group discussions, students prepared questions for guest speakers who attended class. For example, a restorative ecologist presented her work related to wolf impacts in Yellowstone National Park, along with helping to connect the discussion to Northern California. Additionally, a local sheep rancher presented his experiences dealing with wolves on his ranch. Furthermore, as a culminating activity at the end of the ecology unit/SSI on wolf management, each group wrote an eight-page management plan and presented it from their assigned perspective. The presentations took the form of a

townhall-style meeting where one student was randomly selected from each group to serve as a member of the ‘town council,’ which would ultimately synthesise and derive a recommendation for California. During the presentations, students considered the proposals from their assigned perspectives. After each group presentation, opportunities were provided to argue and offer rebuttals. Upon completion of the townhall meeting, participants were given the opportunity to refine their final management plan.

The learning experiences were scaffolded in a manner to promote increased higher-order thinking, ultimately leading to the creation of an original management plan. This scaffolded approach was evident in the manner in which students considered various perspectives. First, students engaged with written text and were asked to read and reflect on it from the perspective assigned to them. Next, students engaged with stakeholders and considered the stakeholders’ perspectives through the lens of their assigned perspective, where they could ask questions and consider the emotive nature of the stakeholders’ responses. Finally, the students created an original management plan representing their assigned perspective which required the students to synthesise the cognitive, affective, and sociocultural aspects of the wolf management issue while also anticipating potential limitations of their plan.

Coding qualitative data

A grounded theory approach was implemented for coding qualitative responses. Upon completion of the ‘town council’ planning meeting, students were asked to reflect on the experience by responding to the following three questions:

- (1) To what extent, if any, has your ability to consider other perspectives changed after completing this project?
- (2) Describe any aspects of the project that influenced your ability to consider others’ views?
- (3) Not including working with others, which aspects of the project did you find challenging?

The first author read student responses and developed initial taxonomic schemes related to perspective taking based on student responses. The original taxonomic schemes were then refined into more systematic coding categories using a constant comparison method (Glaser & Strauss, 1967; Lincoln & Guba, 1985; Patton, 2002). The two authors independently read 33% of those student responses and compared their coding. The authors discussed and resolved any discrepancies, while also negotiating any emerging themes. A second round of independent coding took place implementing the new codes followed by a discussion between the authors to clarify or revise codes. A third round of independent coding was conducted and discussed to ensure fidelity between the authors. Finally, all responses were independently coded using the revised codes and discussed resulting in a 95% interrater reliability.

Results

Overall, the results indicate that students reported changes to their perspective taking, ranging from superficial changes to deep structural changes. Students reported that

researching and reading about the issue, interacting with guest speakers, and engaging in group presentations where the most influential aspects of the immersive experience as it relates to perspective taking. Finally, conceptual understanding of wolf management changed from increased awareness and gaining factual knowledge to an understanding of the complexity of the issue. [Table 1](#) provides a more fine-grained analysis of each taxonomic code mentioned above, while [Table 2](#) provides student exemplars for each code along with the percentage of students who demonstrated each type of response. It should be noted that the student exemplars provided in [Table 2](#) were selected for presentation because they represented the archetypal response for the identified taxonomy as agreed upon by the authors. The exemplars, thus, provide the reader with a representation of typical responses for each taxonomy, while also serving as benchmarks during the coding process; however, it can be safe to assume any given archetype is representative of 97% of students' responses within a given taxonomy.

Research question one sought to determine the extent to which students could identify shifts in their socioscientific perspective taking (SSPT). Students' responses to the reflective questions were analysed to determine if they identified a change in their perspective

Table 1. Detailed descriptions of taxonomic codes.

Taxonomic Code	Description of Code
Identified Shifts in Perspective Taking	
Superficial change	Expressed superficial or generalised changes in perspective taking in one of two ways. In the first, students simply stated that there had been a change, but did not assign a degree of change or claimed to begin the SSI experience already considered other perspectives and felt they had increased their ability to do so but failed to demonstratively convey it.
Deep structural change	Deep structural changes in perspective taking acknowledged the consideration of evidence that markedly impacted how students understood the thoughts and feelings of the stakeholders impacted by wolves in Northern California
Impactful Aspects of the Experience	
Research/reading about the issue	Explicitly identified either or both activities without reference to any other portion of the SSI experience. Students privileged researching and reading about wolf management as key to their ability to consider the perspectives of the other stakeholder groups without identifying any other aspect of the SSI experience.
Impactfulness of guest speakers	Identified either specific speakers (e.g. restorative ecologist, sheep rancher, wolf advocate) or referenced them generally.
Engaging in group presentations	Attributed the ability to consider various perspectives to some aspect of engaging with classmates during the town hall group presentations that served as the culminating event for the SSI. These statements speak to both the value of hearing the perspectives presented, but also the importance of being able to critique those perspectives against another perspective.
Conceptual Change in Students' Understanding	
Increased awareness of wolf management issue	Student had no or limited awareness of the issue of wolf management in California prior to the SSI but fail to recognise the sociocultural aspects associated with the issue.
Factual knowledge	Explicitly acknowledged an increase in the amount of information and/or facts related to wolf management without identifying the source of the information. These types of statements report gains in knowledge, but do not attribute a particular source to these gains, nor making no mention of any of the sociocultural aspects of the issue.
Understanding the complexity of the issue	Statements included an awareness of other perspectives, while also demonstrating a more detailed understanding of the issue, including sociocultural aspects (e.g. socioeconomic status, ethnicity). This differs from an awareness of several perspectives in that understanding the complexity of the issue requires that an awareness of perspectives is necessary, but also requires a more in depth understanding of the issue and the underlying sociocultural influences associated with it.

Table 2. Student Exemplars of Taxonomic Codes and Percentage of Students.

Code	Student Exemplar	Percentage of Students
Research Question 1: Identified Shifts in Perspective Taking		
Superficial change	Prior to the project, I had not considered wolf management in California at all, let alone think of other people's perspectives. OR I have always tried to view others' opinions, maybe to a fault ... So while I am firm in what I believe it isn't hard for me to see others' views and see why they believe what they believe. This activity did a good job of humanising other perspectives on the wolves' issue that most people would either agree or disagree with.	55
Deep structural change	My ability to consider other viewpoints regarding the wolf dilemma has greatly increased. It is so interesting to hear facts and personal opinions from all interested parties. Information is so important when developing opinions. After the group presentations, I considered information that I hadn't even thought about before.	45
Research Question 2: Impactful Aspects of the Experience		
Research/reading about the issue	Researching a hunter's perspective increased my ability to argue from a different viewpoint considering I did not personally agree with a hunter's perspective. Looking at the issue from an economic perspective trained me to think of issues in multi-faceted ways.	18
Impactfulness of guest speakers	Learning about the effects of wolves that I wouldn't have typically thought of was very eye-opening for me. For example, learning that a wolf's presence can stress out livestock and affect their weight and growth was an effect I hadn't considered. Learning about these important details that have a huge impact on some people's lives made me more understanding of different perspectives. Even though we were assigned perspectives for this project, I am not directly impacted by wolves entering California, so before learning about the topic, it was easy for me to see it in black and white. I don't know if it's considered part of the project but hearing the guest speakers also made me more open to other's views. Hearing from people who are directly impacted and involved makes it difficult to judge them only for their opinions about wolves instead of seeing them as people who want what's best for their families and investments.	18
Engaging in group presentations	Each presentation was great and offered up evidence and advice on how to handle the wolves. I would not know off the top of my head how the Native American tribes want to handle the wolves compared to the hunters, so it was cool hearing those views. I also enjoyed the debate and rebuttals. This was a way for each group to talk about their concerns for the other conflicting management plans.	61
Research Question 3: Conceptual Change in Students' Understanding		
Increased awareness of wolf management issue	Before this project, I didn't even know wolves had been roaming Northern California. When the project was introduced, I believed that wolves should be left alone or have the least human interaction possible. This project allowed me to get a view of others' perspectives and understand what has influenced their stand on this issue.	5
Factual knowledge	I learned many interesting facts and a deeper knowledge and understanding about the impact that wolves have in different sectors of society. From the presentations given by the different groups I learned that the solutions proposed for the management of wolves in California are comprehensible and most of the propositions made promote the coexistence between humans and wolves.	5
Understanding the complexity of the issue	In the beginning I was in the middle but considered the activists part a little more, but after all that has been said and presented, I was able to see other sides such as the ranchers, on why it's so	41

(Continued)

Table 2. Continued.

Code	Student Exemplar	Percentage of Students
	important to keep an eye on the wolves and how it can affect them immensely. I'm also able to consider the amount of money it takes to take care of cattle/ sheep and doing observations on wolves, seeing how all perspectives have their reasons on why wolves should be seen a certain way.	

and, if possible, the nature of that shift. The responses indicate that a notable change of perspective-taking shifts occurred in all students, but the degree to which perspective taking changed varied. It is important to recognise that in addressing the first research question, we were not interested in changes to students' opinions about wolf management; rather, we were interested in students' recognition that multiple stakeholders existed with a variety of thoughts and feelings related to wolves in Northern California. Two main themes were identified and categorised as either superficial change or a deep structural change in relation to perspective taking. Typically, the responses coded as superficial acknowledge that a shift in perspective taking had occurred, but students did not elaborate on the nature of the change. For example, the student exemplar for superficial change in Table 2 shows that the student identified a change in their perspective taking abilities but does not provide concrete details to explicitly support how they identified the change. By comparison, the exemplar in Table 2 for deep structural change, includes the recognition of change along with explicit detail derived from the SSI experience to support their decision. To use Kahn and Zeidler's (2019) description, statements coded as superficial change identify a change in position (i.e. where they stand on the issue), existence of other positions, or orientation (i.e. how they approach the issue relative to others). In contrast, deep structural change statements go a step further and are qualitatively distinct in acknowledging a change from their original perspective (i.e. how they perceive and interpret the issue). Fifty-five percent of students reported statements consistent with superficial changes in perspective taking, while 45% reported examples consistent with deep structural changes from their original perceptions and interpretations of the issue.

The second research question sought to determine which experiences associated with the SSI intervention were personally impactful in students' shifts in their perspective-taking. Three key aspects of the experience were identified by the students: researching/reading about the issue, interacting with guest speakers, and engaging in group presentations. These aspects were mentioned specifically in the students' responses. The exemplars in Table 2 clearly reference a specific experience from the SSI (e.g. researching about ranchers, hearing directly from people impacted by an issue, listening to the presentations of key stakeholders, and asking questions). Analysis of data indicated that students who identified reading/researching as impactful stated that this was significant because it (1) provided a deeper understanding of the issue, (2) identified solutions, and (3) increased their factual knowledge. Statements indicating that the presentations of key stakeholders were impactful provided the following reasons: (1) increased factual knowledge, (2) better understanding of opposing opinions, and (3) better understanding of how wolves impact stakeholders' lives. Finally, students who identified guest speakers as impactful justified their answer in the following ways, (1) increased their factual knowledge and (2) increased

their understanding of the financial and emotional impact wolves have of a stakeholder. Both researching/reading about the issue and interacting with guest speakers each were identified by 18% of students as being particularly impactful in their perspective taking changes. Engaging in group presentations was identified by 61% of students.

The third research question focused on students' gains in conceptual understanding of the subject matter after participating in the SSI experience. Recognising the complexity of an SSI is considered an indication of conceptual understanding (Sadler et al., 2007). If thought of as a continuum, attempting to simplify an SSI to a single cause and effect relationship would fall at the low conceptual understanding end of the continuum, while evaluating multiple conflicting types of evidence would be the opposite end of the continuum. Three novel themes emerged from the data: (1) increased awareness of the issue, (2) factual knowledge, and (3) awareness of the complexity of the issue. Statements identified as *awareness of the issue* differ from *understanding the complexity of the issue* in that the former only recognises that the issue exists, while the latter demonstrates a deeper understanding of the issue. Statements identified as increased awareness alluded to becoming aware of wolves in California for the first time and would be considered near the low conceptual understanding end of the continuum, as the individual did not indicate any attempt to resolve the issue. Any statement that identified the acquisition of new facts about wolves in California was considered to be an increase in factual knowledge and indicate that the individual is starting to recognise the complexity of the issue. Finally, statements considered to be awareness of the complexity of the issue provided details about the impact of the issue on various stakeholders. Individuals who provided statements recognising the complexity of the issue have, according to Sadler and colleagues (2007) started to, 'recognize the multiple, dynamic interactions within SSI which preclude simple, linear solutions' (p. 375). An increased awareness of the issue and increased factual knowledge each was identified by 5% of students. Understanding the complexity of the issue was mentioned by 61% of students. The results of RQ3 indicate that a type of hierarchy of perspective taking developed as a result of engaging in the SSI experience, with the students who demonstrated an understanding for the complexity of wolf management subsuming the other groups because it can be inferred that in order to understand the complexity of the issue, one must recognise that the issue exists and have enough knowledge to recognise the diverse factors influencing the issue.

Discussion

Scaffolded experiences

The results from this manuscript support the recommendation that implementing empirically supported interventions from other academic disciplines can promote functional scientific literacy in science education through fostering SSPT, as described in the HARTSS Model (Kahn & Zeidler, 2016). Specifically, a reading and writing intervention from Language Arts education was embedded within an environmental SSI to promote students' ability to recognise shifts in their perspective taking abilities. Our results indicate that students were better able to recognise shifts in their perspective taking after engaging in a SSI experience that implemented a perspective reading and writing intervention. All students who participated acknowledged that they were more adept at considering

differing perspectives for a myriad of reasons, reflecting the scaffolded experiences of the course. For example, students were required to read and research as part of several assignments prior to interacting with guest speakers or engaging in classroom debate. The initial reading/researching influenced the types of interactions the students had with guests and their peers. Consequently, students may have overlooked the significance of the former experience in favour of the latter. This is consistent with the description of a cumulative epiphanic event that is the result of a buildup of experiences that have occurred over time and have built up. The event that is remembered is a symbolic representation of several other events that have led to the epiphany (Denzin, 2001).

The scaffolded design used in this study and advocated in SSI scholarship may have impacted students' ability to identify a single activity that was particularly impactful on their perspective taking because each new activity integrated previous activities. The evidence suggests that explicit implementation of perspective taking interventions can promote an increased awareness of perspectives and is consistent with previous literature that theorised such interventions might be effective (Kahn & Zeidler, 2016). Furthermore, the evidence supports Kahn and Zeidler's suggestion that scaffolding perspective-taking experiences can expand students' cognitive flexibility and reflection.

The results are also aligned with the findings of previous studies on socioscientific reasoning (SSR) and the role of perspective-taking in the resolution of contentious socio-cultural issues (Sadler et al., 2007). Specifically, Sadler et al. claim that students must analyse the issue from multiple perspectives if they are to resolve a given issue. Additionally, Sadler and colleagues recognised the difficulty in facilitating perspective-taking when alternative perspectives vary from the student's own perspective. The authors of the current study repeatedly embedded the reading and writing intervention within a series of scaffolded experiences to explicitly address Sadler et al.'s observed difficulties. The participants in this study needed to consider various perspectives while negotiating the issue of wolf management in order to successfully complete the reading and writing intervention implemented in the study, as well as the other experiences in the SSI.

Authentic experiences and a moral context

The context within which students engage with SSI critically important to promoting functional scientific literacy. Sadler (2009) and Herman (2018) contrast how 'impoverished' learning environments (e.g. hypothetical and contrived scenarios) and 'rich' learning environments (e.g. authentic and relevant issues) impact students' preparation to help resolve SSI in ecologically and culturally sustainable manners. Rich experiences allow students to become immersed in the SSI and interact with stakeholders impacted by the SSI. Sadler and Herman argue that leveraging the students' relationships to the place the SSI occurs and the people impacted by the SSI promote an etic/emic shift necessary to promote perspective taking. Furthermore, the central role of authenticity in connection to students' discussions of SSI-related problems has been recognised by Åkerblom and Lindahl (2017). With this in mind, the SSI in the current study provided as a rich a learning context as possible by focusing on an issue that was locally relevant to students, exposing students to stakeholders impacted by the issue, and engaging in classroom debate.

The results indicate that while 18% of students specifically identified the reading and writing intervention as vital to their ability to recognise shifts in their perspective

taking, other aspects of the course were also impactful with respect to students' changes in their perspective taking abilities. Those students who identified the guest speakers and group presentations frequently mentioned the significance of the affective component of the interaction, as evidenced by the reasoning for the significance (e.g. understanding the sociocultural aspects, a better understanding of the impact of wolves on stakeholders' lives). The participant exemplar of *Impactfulness of Guest Speakers* theme used above clearly points to the influence that understanding the perspective of a rancher as a protector and provider for his family and animals had on the students. All of this exemplifies Kahn and Zeidler's (2019) claim that SSPT requires an authentic engagement with those impacted by a given issue. This also supports the work of those that advocate the position that transformational science education necessitates the sense of ownership, commitment and authentic engagement to issues of societal and political importance (Bencze et al., 2012; Bencze, et al., in press; Tal et al., 2011; Zeidler, 2014). By speaking with a rancher and ecologist, along with viewing a wildlife advocate speak with previous students, the participants engaged with others and their circumstances related to wolves thereby having the opportunity for coordinating ethic with emic perspectives.

Ultimately, the participants in the study reached consensus on how to best manage wolves in Northern California in a manner that was acceptable to all the stakeholders represented in the project. Here we can see the importance of a moral context for SSPT (Kahn & Zeidler, 2019). In the absence of moral context, resolving an issue such as wolf management in California would be as simple as implementing policies that are in the best interest of a particular group of people. However, because the participants forecasted the consequences of potential solutions, we argue, there was broadening of their perspectives to include a moral element and presumably empathetic understanding of the issue and its consequences. This is consistent with the work of Herman et al. (2018) who found that students expressed forms of empathetic dissonance toward people and nature impacted by environmental SSI including deep compassion for those experiencing SSI hardships, guilt for not resolving SSI, anger toward those that are perceived to cause SSI, and righteous indignation when the moral principles of equity and justice were violated because of SSI impacts.

Theoretical implications

Many studies have examined changes to the quality of students' arguments after participating in SSI instruction (e.g. Albe, 2008; Kolstø, 2006; Martin-Gamez & Erduran, 2018; Sadler, 2004) and have identified perspective taking as an important skill associated with effective argumentation. Fewer studies have considered the explicit pedagogical decisions made by teachers to facilitate improvement in argumentation by addressing perspective-taking (Dawson & Venville, 2010). The current study differs from Dawson and Venville's work in that it moves beyond instructors simply modelling perspective taking or 'playing devil's advocate.' The present study removed an external authority (i.e. their instructor) and required students to consider the sociocultural aspects of the SSI through several scaffolded perspective-taking activities, culminating in a debate that required students to consider sociocultural aspects of the SSI, thus making perspective-taking strategies more accessible for students.

The current study also provides an empirical link between social perspective-taking theories and the SSI theoretical framework (Martin et al., 2008; Selman, 1971; Zeidler et al., 2005). Social perspective-taking advocates point to the importance of engaging with both the physical and sociocultural world where individuals must negotiate and coordinate between anthropocentric and ecocentric perspectives (Herman et al., 2019). Similarly, while it has been discussed elsewhere in the SSI literature (see Sadler et al., 2007; Zeidler & Newton, 2017) that discourse and argumentation are critical components of the SSI framework as means of analysing claims and evidence, the current study sheds light on how discourse and argumentation foster increased perspective taking. Here we have demonstrated how students' explicit identification of student-to-student and student-to-stakeholder interactions are pivotal to their changes in perspective-taking ability, which demonstrates the crucial role that social interactions play as people negotiate SSI in general, or contentious environmental issues in particular.

Pedagogical implications

The results support the claim that using scaffolded perspective taking experiences, like a perspective reading and writing intervention in science education is effective in terms of increasing students' mental representations of viewpoints. Educators looking to address content standards (e.g. Next Generation Science Standards, Australian Curriculum) while also developing the type of scientific literacy that will be useful for all students, regardless of their future careers, can use the interventions from this study to guide the design of their courses while also learning science in a manner congruent with the goals of the international community. For example, the United Nations Educational, Scientific, and Cultural Organization (UNESCO) has identified the need for a participatory citizenry capable of identifying and resolving problems on the national and international level. Thus, the international community has recognised the importance of not only emphasising science content knowledge, but also considering the ethical implications associated with science, technology and innovation (UNESCO, 2019).

Limitations and future research

As with any study, there are limitations that bound this study. First, certain aspects of the course may be difficult to replicate; specifically, being immersed in an area where the wolf management controversy is so abundant made access to stakeholders extremely easy in this study. Future studies should consider the effectiveness of using existing technologies, like teleconferencing software or virtual reality to overcome the issue of access. Furthermore, the proximity of the issue to many of the students' lives may have had unexpected impacts on their ability to consider novel perspectives or limited their ability to reflect on the issue for fear of repercussions from family or friends.

A second concern is the nature of the sample of this study, which focuses on a small group of culturally homogeneous postsecondary students. This was a necessary reality working with intact groups of students registered in a real course in a particular university setting. It would be prudent, however, if future research could focus on the implementation of the HARTSS model of perspective-taking and expanded this work to include students of various heterogeneous educational contexts.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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