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RESEARCH ARTICLE

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Students' environmental NOS views, compassion, intent, and action: Impact of place-based socioscientific issues instruction

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Abstract

Preparing students to achieve the lofty goal of functional scientific literacy entails addressing the normative and non-normative facets of socioscientific issues (SSI) such as scientific processes, the nature of science (NOS) and diverse sociocultural perspectives. SSI instructional approaches have demonstrated some efficacy for promoting students' NOS views, compassion for others, and decision making. However, extant investigations appear to neglect fully engaging students through authentic SSI in several ways. These include: (i) providing SSI instruction through classroom approaches that are divorced from students' lived experiences; (ii) demonstrating a contextual misalignment between SSI and NOS (particularly evident in NOS assessments); and (iii) framing decision making and position taking analogously—with the latter being an unreliable indicator of how people truly act. The significance of the convergent parallel mixed-methods investigation reported here is how it responds to these shortcomings through exploring how place-based SSI instruction focused on the contentious environmental issue of wolf reintroduction in the Greater Yellowstone Area impacted sixty secondary students' NOS views, compassion toward those impacted by contentious environmental issues, and pro-environmental intent. Moreover, this investigation explores how those perspectives associate with the students' pro-environmental action of donating to a Yellowstone environmental organization. Results demonstrate that the students' NOS views became significantly more accurate and contextualized, with moderate to large effect, through the place-based SSI instruction. Through that instruction, the students also exhibited significant gains in their compassion for nature and people impacted by contentious environmental issues and pro-environmental intent. Further analyses showed that donating students developed and demonstrated significantly more robust and contextualized NOS views, compassion for people and nature impacted by contentious environmental issues, and pro-environmental intent than their nondonating counterparts. Pedagogical implications include how place-based learning in authentic settings could better prepare students to understand NOS, become socioculturally aware, and engage SSI across a variety of contexts.

KEYWORDS
nature of science, place-based education, pro-environmental behavior, socioscientific issues

1 | INTRODUCTION

Promoting "scientific literacy" clearly dates back to the 19th century and persists in current reforms and standards documents internationally (AAAS, 1990; Abd-El-Khalick et al., 2004; DeBoer, 2000; NGSS Lead States, 2013). Among the justifications for scientific literacy are technocratic and economic reasons, such as bolstering international standing and producing more scientists and engineers. Invoking work from Dewey (1966/1966) and Eliot (1898), more compelling purposes for scientific literacy discussed in current science education literature includes empowering people to function more effectively in a democracy (DeBoer, 2000; Hodson, 2009; Zeidler et al., 2016).

The varied goals for scientific literacy are reflected in expectations about what ideas students should learn and how they should learn them. On one hand, scientific literacy has been limited to merely focusing on the non-normative components of science including its products (e.g., laws and theories) and processes (e.g., methodological concerns). This restricted focus aligns with Vision I scientific literacy as described by Roberts (2007), the science, technology, engineering, and mathematics deficit framework admonished by Zeidler (2016), and the economic and technocratic ends for science education alluded to above. On the other hand, functional literacy about science and technology assumes engagement with broader perspectives that integrate non-normative with normative (e.g., prescribing courses of actions, considering diverse cultural perspectives) components. This more encompassing scientific literacy framework reflects Roberts (2007) Vision II for science education and initiatives like the science, technology, engineering, arts, and mathematics movement (Zeidler, 2016) that encourage students' engagement of socioscientific issues (SSI), which are complex and controversial scientific matters that entail political, moral, and sociocultural implications that are experienced at varying magnitudes. Promoting such humanistic educational approaches includes helping students develop more robust and holistic understandings of the nature of science (NOS) and character and values that foster sociocultural awareness and a sensitivity for diverse groups impacted by SSI (Herman, 2015; Lee et al., 2013). In the case of SSI that take the form of contentious environmental issues, such as climate change or the introduction (or reintroduction) of flora and fauna into natural communities, NOS considerations could include how environmental scientists and ecologists investigate, comprehend, communicate about, and recommend managing how those issues impact ecosystems. Sociocultural considerations could include being concerned about how local and indigenous communities perceive those contentious environmental issues and how their traditions, livelihoods, beliefs, and identity may be impacted through the resolution of those issues.

Situated within the more encompassing framework of functional scientific literacy that integrates non-normative with normative science considerations, this investigation explores how place-based SSI instruction focused on the contentious environmental issue of wolf reintroduction in the Greater Yellowstone Area impacted secondary students' perspectives regarding NOS, compassion for nature and people impacted by contentious environmental issues, and pro-environmental intent (e.g., willingness to fundraise for environmental causes). This investigation also takes a novel step by determining how those perspectives associate with students' enacted pro-environmental behavior of donating to a Yellowstone environmental organization.

1.1 | SSI as a context for NOS engagement

Among the major challenges science educators confront include providing instructional contexts that exhibit clear and purposeful relevance to students and the issues they may face (Gilbert, Bulte, & Pilot, 2011). Several researchers have established that SSI can provide contextualized access points for considering NOS, and postulated that possessing such knowledge enables more informed and responsible socioscientific decisions (Allchin, 2011; Eastwood et al., 2012; Herman, 2015; Hodson, 2009; Khishfe, 2012, 2014; Sadler, Chambers, & Zeidler, 2004). However, empirical studies have yet to consider how NOS understanding may be linked to enacted behaviors representative of contemplative socioscientific decision making in real-world contexts. This investigation aims at advancing a research base that considers how students engage SSI and NOS in more authentic and sophisticated ways (Kampourakis, 2016; Karisan & Zeidler, 2017).

Sadler et al. (2004) investigated how secondary biology students engaged NOS through SSI when evaluating two conflicting written "science-briefs" about global warming. While the students demonstrated an affinity for the briefs aligning with their personal beliefs (i.e., confirmation bias), they were provided a contextualized venue to contemplate NOS (e.g., empiricism, tentativeness, and how science is impacted by societal factors). Wong, Hodson, Kwan, and Yung (2008) used the 2003 severe acute respiratory syndrome (SARS) outbreak in Hong Kong to highlight for student teachers several NOS aspects (e.g., tentativeness, theory-ladenness, and intersection with sociocultural and political factors). Notably, the impact of the SARS instruction appeared to be due to its relevance to the student teachers' lives and inclusion of video interviews of SARS scientists (Allchin, Andersen, & Nielsen, 2014; Wong et al., 2008). Focusing on how NOS associates with socioscientific argumentation, Khishfe (2012) compared two groups of ninth grade students, one that received instruction on formulating arguments related to genetic engineering and another that received similar instruction but also learned how to apply NOS to their arguments. While both groups stated similar support for genetic engineering, the group explicitly taught NOS utilized those ideas (e.g., tentativeness, empiricism, subjectivity) more to justify their positions. Khishfe (2014) later showed that NOS views acquired through one SSI context can impact engagement with closely related SSI contexts. Finally, Eastwood et al. (2012) compared the impacts of explicit NOS instruction delivered through content driven and SSI driven contexts on secondary students NOS conceptions. While both groups demonstrated significant NOS understanding gains, those experiencing the SSI context used examples to explain social and cultural NOS aspects.

Recent studies have more intently focused on the intersection between NOS understanding and sociocultural factors during SSI engagement. Zeidler, Herman, Ruzek, Linder, and Lin (2013) showed that among a cross-cultural group of students, those exhibiting the most sophisticated epistemological views about science also made simulated organ donation decisions that were utilitarian in nature and reflected their cultural norms, whereas students with less sophisticated views typically made choices based on immediately recognizable concerns and outcomes. In addition, Herman (2015) demonstrated that secondary marine science students' global warming science perceptions (e.g., the extent global warming science proceeds via controlled experiments) and sociocultural grouping (e.g., ethnicity, socioeconomic classification) interactively influenced their willingness to mitigate global warming through actions requiring varying levels of sacrifice. In summary, the current research base appears to have established that effectively engaging SSI entails balancing, among many factors, the contextual features of NOS and sociocultural concerns.

1.2 | SSI as a context for promoting character, values, and compassion for others

In addition to promoting NOS, SSI that are engaging to students provide contexts for considering the humanistic and normative components associated with science (Karisan & Zeidler, 2017; Zeidler, 2016). These include an ethic of care, empathy, and concern for nature and people impacted by SSI (Lee et al., 2013; Sadler & Zeidler, 2005). Sadler and Zeidler (2005) demonstrated that 30-college students provided emotive care-based (e.g., empathy for others), rationalistic reason-based (e.g., weighted calculations of treatment availability and side effects), and intuitive immediate response reactions to six genetic engineering dilemmas. Lee et al. (2013) investigated the impact of an SSI genetic modification instructional program on 132 ninth-grade students' development of character and values as global citizens. Findings from this study indicate that the SSI instruction influenced the students to become more sensitive toward the moral aspects of science and technology developments and those impacted by those developments. Interestingly, while the students felt a personal accountability to resolve genetic SSI, they struggled to exhibit the willingness and efficacy to do so.

A few studies address peoples' reactions to topics similar to the Yellowstone wolf reintroduction issue addressed in the investigation reported here. Hermann and Menzel (2013) demonstrated that a large sample ($n = 1,243$) of secondary students' intentions to support wolf reintroduction in Germany was predicted by their wildlife value orientations (e.g., interest and appreciation for wildlife) and emotive concerns such as fear of wolves and ethical considerations that accompany wildlife reintroduction efforts. Implications from this investigation included the need for educating students about wildlife management and the importance of ethical emotions regarding wildlife and human coexistence to promote ecologically sustainable decision-making processes. Finally, Herman, Sadler, Zeidler, and Newton (2018) demonstrated that postsecondary students who experienced place-based instruction about Greater Yellowstone Area contentious environmental issues (e.g., brucellosis in bison, wolf reintroduction) expressed nuanced forms of empathy toward people and nature impacted by those issues.

2 | PURPOSE

To the author's best knowledge, no studies firmly establish how NOS understanding and compassion for others that is promoted through SSI instruction relate to significant personal decision making and action. This may be due to at least three methodological or conceptual issues regarding the aforementioned studies' approaches (e.g., Herman, 2015; Khishfe, 2012). First, most extant SSI intervention studies targeted toward promoting NOS views have employed generic decontextualized assessment items focused on a few declarative NOS aspects (e.g., subjectivity and tentativeness); and items presenting contexts irrelevant to SSI (e.g., presenting prompts about atoms and dinosaurs on the VNOS and VNOS-C). These instruments may inhibit capturing students' expression of important contextualized NOS features as they relate to other important SSI considerations (e.g., sociocultural concerns). A number of authors have raised this precise concern (Allchin, 2011; Allchin et al., 2014; Clough, 2006; Hodson, 2009; Karisan & Zeidler, 2017; Matthews, 2012). Hodson (2009, p. 29) sums the point up well:

> Decontextualized questions. . .can seem infuriatingly vague to the student and be met with seeming incomprehension. . .Conversely, context embedded questions have domain specific

> knowledge requirements that may sometimes preclude students from formulating a response that properly reflects their NOS views…Put simply, questions set in one context may trigger different responses from essentially the same questions set in a different context.

Therefore, assessments must be used that better account for how students' contextual NOS views, sociocultural awareness, and compassion for others develops through SSI interventions (Karisan & Zeidler, 2017).

Second, situated learning theory could inform how students are immersed within authentic socioscientific contexts (Sadler, 2009). Unfortunately, school science typically is divorced from the contexts in which SSI are investigated and often eschews the sociocultural implications SSI resolution entails. If SSI instruction occurs, the learning and assessment is often implemented through means aligned with traditional learning environments and discrete learning goals such as hypothetical scenarios removed from an actual naturalistic experiential setting. Such experiences can appear as abstractions removed from students' lives and perpetuate the gap between science communities and school science, which inhibits students from actively resolving SSI in real world contexts. Two rare exceptions discussed above are Wong et al. (2008) who utilized students lived experiences during the SARS outbreak, and Herman et al. (2018) who provided students authentic SSI experiences in Yellowstone.

The third issue relates to the how extant investigations have framed socioscientific decision making, and the extent participants were required to make invested choices indicative of how they would *actually* act. Specifically, the "decisions" made by students in most investigations better resemble position statements regarding particular SSI outcomes (e.g., Khishfe, 2012), or a willingness to mitigate SSI (e.g., Herman, 2015). This limitation is also present in the vast majority of pro-environmental behavior studies where it has been demonstrated a scant 20% overlap exists between stated intentions and actual behaviors (Gifford & Nilsson, 2014; Kormos & Gifford, 2014). Therefore, a question can be raised regarding the extent verbal or written positions truly represent how people will act when faced with real choices requiring significant personal sacrifice.

The present investigation's significance lies in how it methodologically responds to those three issues and builds upon the corpus of existing work described above through exploring how place-based SSI instruction focused on the contentious environmental issue of wolf reintroduction in the Greater Yellowstone Area influenced secondary students' NOS views, compassion toward those impacted by contentious environmental issues, and pro-environmental intent. Moreover, this investigation explores how those perspectives associate with the students' pro-environmental action of donating to a Yellowstone environmental organization. This study seeks to answer the following questions:

1. How are students' NOS views impacted through place-based SSI instruction focused on a contentious environmental issue; and how are those views associated with pro-environmental action?
2. How are students' compassion toward humans and nature impacted through place-based SSI instruction focused on a contentious environmental issue; and how is that compassion associated with pro-environmental action?
3. How are students' pro-environmental intent impacted through place-based SSI instruction focused on a contentious environmental issue; and how is that intent associated with pro-environmental action?

3 | DESIGN AND METHODS

A convergent parallel mixed-methods approach with concurrent triangulation was used to investigate the research questions outlined above (Cresswell, 2014; Creswell & Plano Clark, 2011). This design entails aligning the collection and analysis of qualitative and quantitative data, and giving both of those forms of data equal priority during interpretation in order to facilitate a high degree of cross-validation and corroboration of findings. The participants, their learning experiences, and data collection and analysis are described below.

3.1 | Participants and learning experiences

Sixty-two students self-selected to participate on a school sponsored trip to Yellowstone National Park where they experienced the place-based SSI instruction focused on wolf reintroduction. Of these, 60 agreed to participate in this study and sufficiently completed all data sources. The investigated students consisted of a relatively even distribution of males ($n = 31$) and females ($n = 29$) who were enrolled in 7th ($n = 23$), 8th ($n = 19$), 9th ($n = 13$), 10th ($n = 4$), and 11th ($n = 1$) grades in a medium sized city school district in central Missouri. The school district employs a standard science curriculum that addresses fundamental ecosystem topics (e.g., trophic cascade and food webs) in the 6th grade relevant to ideas addressed through the place-based SSI instruction. Most of the students resided in urban and suburban settings (80%), while a smaller percentage of the students lived in nonagricultural (15%) and agricultural (5%) rural settings.

3.2 | Study context

Table 1 presents an overview of the Yellowstone place-based SSI instruction experienced by the students. Implementation largely followed the SSI design elements as outlined in Herman et al. (2018), with the contentious environmental issue of wolf reintroduction being presented early in the experience. The wolf reintroduction issue exemplifies the contention between those whose goals for the Greater Yellowstone Ecosystem are environmental preservation and economic utility; with the controversy surrounding this issue being intensified because of the inequities in social power and conflicting views about property use and nature among those involved (Smith & Bangs, 2009; Wilson, 1997).

Scaffolding experiences were employed throughout the place-based SSI instruction to facilitate students' deep contemplation of the many complex dimensions that wolf reintroduction entails, such as how wolves impact the Greater Yellowstone Ecosystem, how ecologists research that impact, and the historical, political, cultural, and ethical implications associated with wolf extirpation and reintroduction. The SSI instruction was reflective, discussion based, and included planned and spontaneous learning experiences occurring across variety of settings from large-group instruction occurring in the field to small-group instruction occurring in vans between destinations.

To provide context, the SSI instruction began with concrete experiences regarding the wolf reintroduction issue such as documentaries (CBS, 2007a, 2007b; PBS, 2010), wolf watching, and field interactions with ecologists who were involved with wolf reintroduction efforts including research and outreach. These experiences provided a venue for more abstract instruction such as contextualizing NOS and the cultural, political, historical, and ethical facets of wolf extirpation and reintroduction. For instance, on day 3, the students hiked to a riparian area and then an abandoned wolf den and were instructed to note and speculate about the causes for the variation in the browse heights of the willow and aspen stands in those areas. After the students considered the vegetative variation in both areas, the wolf ecologists and author delivered field instruction about scientists' diverse research approaches, the inadequacies of the top–down trophic cascade model to account for the wolves' complex impact on Yellowstone flora and fauna, and the cultural and ethical facets of wolf extirpation and reintroduction. A selection of the discussion between the wolf ecologists and students appears below:

TABLE 1 Sequence of the place-based Yellowstone SSI instruction

Day	Primary place-based SSI instructional experiences (in order)
1	A. Students complete pre SEEDSII B. Students watch documentaries and engage in discussion led by the instructor/author regarding wolf extirpation and reintroduction. Documentaries include: *Hunting Wolves Saving Wolves* (PBS, 2010), *Wondering About Wolves, Wolves of Yellowstone Spur Love and Hate* (CBS, 2007). Themes explicitly addressed during documentaries and discussions include introductory concepts regarding: (i) how ecologists investigate the natural world; (ii) ecosystem dynamics and how top down trophic cascade may be too simplistic for Greater Yellowstone Ecosystem; and (iii) stake holder perspectives (ranchers' and scientists') and contention about wolf extirpation and reintroduction.
2	A. Students travel through Yellowstone National Park with sporadic stops in order to view wildlife from the road. The instructor/author transfers from van to van and engages small groups of students in discussions about: (i) the esthetic and community value of Yellowstone National Park; (ii) the cultural aspects of Yellowstone National Park management; and (iii) ethical behavior and decision making regarding nature and the environment.
3	A. Students observe wolves and other wildlife while hiking Slough Creek and other areas in the Lamar Valley with the wolf ecologists. The wolf ecologists and instructor/author teaches students in the field about: (i) how ecologists investigate nature through diverse yet valid approaches; (ii) how wolves impact the Greater Yellowstone Ecosystem in diverse ways; (iii) the extent that trophic cascade theory fully accounts for wolves' impact on Yellowstone National Park; and (iv) the scientific, political, and cultural perspectives about wolf extirpation, reintroduction, and contentious environmental issues resolution. B. Students experience an interactive field presentation during lunch provided by a wolf ecologist who tracks wolves in Yellowstone through radio telemetry. The interactive presentation addresses: (i) bioethics and the intrinsic value of wolves and nature; (ii) the history of Yellowstone wolf packs; (iii) the human characteristics of scientists (e.g., becoming personally invested in the wolves' well-being); and (iv) the diverse methodologies scientists use to study wolves (e.g., radio telemetry, observational studies). C. Students read and discuss—*The Legend of the Wolf: Predators are Supposed to Exert Strong Control over Ecosystems, but Nature doesn't Always Play by the Rules*. (Marris, 2014) and competing Yellowstone National Park trophic cascade accounts (Beschta & Ripple, 2013; Kauffman et al. 2013). The instructor/author transfers from van to van and engages small groups of students in discussions about how trophic cascades/scientific models omit many factors (e.g., abiotic, sociocultural factors) and must be reconsidered when resolving SSI. D. After dinner, the students experience an interactive presentation summarizing the themes addressed on day 3 to include NOS instruction about how theories such as trophic cascade can be revised and how ecologists can research the same areas, yet yield different results and conclusions.
4	A. Students hike Mount Washburn where the instructor/author engages them in small group discussions about: (i) different historical and cultural perspectives and empathy (e.g., scientific, Native American vs. Eurocentric, ecocentric and anthropocentric) regarding wolf reintroduction; and (ii) the moral and ethical considerations regarding wolf extirpations and reintroduction. B. Students read and discuss in small groups in vans a narrative about wolf ecology and Aldo Leopold's *Thinking Like a Mountain* (Leopold, 1949). The instructor/author transfers from van to van and engages small groups of students in discussions about how Leopold's perspectives about wolves shifted, sustainability, and the ethical considerations associated with environmental SSI.

(Continues)

TABLE 1 (Continued)

Day	Primary place-based SSI instructional experiences (in order)
	C. Students hike Mammoth Hot Springs Terraces. At the conclusion of the hike, the students experience an interactive presentation summarizing the themes addressed on day 4 to include instruction about perspectives (e.g., scientific, empathetic, sociocultural) involved in contentious environmental issues resolution.
5	A. Students Hike Grand Prismatic, Artists Paintpots, and Old Faithful where the instructor/author engages them in small group discussions about personal major impacts from their Yellowstone National Park experience. Students also share perceptions regarding tourisms, public natural resources use, and contentious environmental issues resolution in the context of Yellowstone National Park management. B. Students gather together at the Hoodoos and share how they were impacted by the Yellowstone experience. They then complete a reflective solo hike where they focus on immersing themselves in nature.
6/7	A. Students travel to Teton National Park where they camp and enjoy a bonfire at Colter Bay. Here, they reflect and share their perceptions of the Yellowstone trip and their emerging views regarding wolf management in Yellowstone National Park. B. Students complete post SEEDSII and choose to donate or not donate to the Yellowstone environmental organization C. Students travel to Jackson and then depart for Missouri.

Wolf ecologist: At this site there are a number of things going on that sort of contradict the trophic cascade theory. For decades, people talked about the aspen stands disappearing in Yellowstone. Why? Because there were so many elk that they were eating them down and there wasn't any regeneration of the aspen stands. We're twenty years into having wolves in Yellowstone Park. There's a lot fewer elk now. The elk aren't really spending a whole lot of time in this area throughout the year. They're still browsing the aspen a little bit, but why aren't we seeing this big pulse of growth that's predicted from the trophic cascade theory? Any ideas?

Students: Lack of water? Global warming?

Wolf ecologist: Lack of water, climate change. I like those…Everyone, take a moment and look around and see if you can find aspen. These have actually been chewed up a little and are to some extent being eaten by the elk. But they also have not grown as much as they should over the decades since wolf reintroduction. They're not getting enough moisture to really grow to be these tall trees that you see around you. In fact this aspen stand may die out and no longer even produce these little aspen that are coming up. That could be because of climate change. If we kind of connect all these dots together and go back to the thought of the trophic cascade that we were talking about earlier, we saw it in some areas, like the tall willow along the rivers that seem to be doing well. However, with aspen stands, some scientists are finding places where they have grown really tall, but others that are not. We just happen to be right at the base of this wolf den, where the aspen growth has not really responded to what the trophic cascade would have predicted. So, again, it's one of these situations where we have to be a little cautious about what we hear in terms of the science — having evidence for one side and evidence for the other, and it can really be a blurred picture of what's going on.

Later, small-groups of students drew from those experiences when reading (see Table 1, e.g., Marris, 2014) and engaging in discussions led by the author. This instruction addressed how competing ecology research groups either supported or challenged the extent that traditional top–down trophic cascade models adequately explained how wolves impacted Yellowstone, and how these ecologists' competing accounts could be inappropriately used to promote special interest groups' agendas and support or protest wolf reintroduction and management efforts.

Important to note, the lead instructor and author possesses advanced degrees in ecology and science education and previous experiences conducting wildlife biology work and NOS and SSI instruction focused on wolf reintroduction in the Greater Yellowstone Area. The accompanying science teachers familiar with the students and wolf ecologists also provided rich experiences that promoted the instruction about wolf ecology research and contentious environmental issues engagement.

3.3 | Instrument development

The socioscientific and ecological engagement dimensions survey II (SEEDSII) was developed specifically for this investigation and presents clusters of Likert and qualitative prompts relevant to contentious environmental issues engagement (Table 2). SEEDSII construction occurred over several steps informed by inputs from secondary students, science teachers, and science education faculty. First, the author and a middle school science teacher with over 20 years of experience and familiarity with the target population collaboratively drew from existing research (e.g., Lee et al., 2013; Liang et al., 2008; Milfont & Duckitt, 2010) to write prompts congruent with the themes addressed through the place-based SSI instruction focused on wolf reintroduction. The author, two science education faculty members possessing extensive experience researching and teaching SSI and NOS, and a practicing middle school science teacher with 13 years of teaching experience then independently reviewed these initial SEEDSII prompts for readability and content validity. The SEEDSII was then edited and piloted with 30 middle-school science students. The students were instructed to thoroughly complete the SEEDSII and convey in writing and verbally which prompts caused them confusion. The students', science education researchers', and teachers' responses and suggestions facilitated a final round of SEEDSII editing for comprehensibility and validity (Bennett, 2001, Osborne, Simon, & Collins, 2003).

The final SEEDSII presents sets of items regarding: (i) trophic cascade and food webs; (ii) five NOS dimensions related to investigating and resolving contentious environmental issues; (iii) two dimensions regarding compassion toward people and nature impacted by contentious environmental issues; (iv) one dimension addressing pro-environmental intentions; and (v) student demographics (see Appendix SA for the SEEDSII). A strength of the SEEDSII is that the items are targeted toward the context of the contentious environmental issue addressed in this investigation. Furthermore, each SEEDSII dimension presents four to seven forced Likert prompts and an open-ended qualitative prompt that requires respondents to explain, with examples, their Likert choices. Using complimentary Likert and qualitative measures through mixed-methods approaches enables the efficacious triangulation and assessment across data sources revealing a large number of nuanced contextual views (Cohen, Manion, & Morrison, 2011; Herman & Clough, 2016). To augment the reliability of this investigation's findings, the SEEDSII presents a concluding prompt that asks participants to explain their difficulties with responding to questions. Specific indicators of the SEEDSII reliability are presented later in the section titled *SEEDSII Data Efficacy*.

3.4 | Data collection

The students completed the SEEDSII in writing immediately before and at the conclusion of the place-based SSI instruction under the supervision of the lead researcher and chaperoning teachers, who were

TABLE 2 SEEDSII dimensions, example items, and reliability/validity measures

		Pre administration			Post administration		
SEEDSII dimension	**Likert example item**	**Cronbach's α/mean IIC**	**% Students indicating confusion (specific items)**	**% Likert and qualitative responses congruent, ambiguous, incongruent**	**Cronbach's α/mean IIC**	**% Students indicating confusion (specific items)**	**% Likert and qualitativeresponses congruent, ambiguous, incongruent**
Methodology of environmental science investigations	Considering what scientists actually do when researching environmental issues, there really is no such thing as a step-by-step scientific method.	0.63/.31	2 (a, b)	91, 7, 2	0.61/0.28	0	100, 0, 0

(Continues)

TABLE 2 (Continued)

SEEDSII dimension	Likert example item	Pre administration			Post administration		
		Cronbach's α/mean IIC	% Students indicating confusion (specific items)	% Likert and qualitative responses congruent, ambiguous, incongruent	Cronbach's α/mean IIC	% Students indicating confusion (specific items)	% Likert and qualitativeresponses congruent, ambiguous, incongruent
Compassion for nature impacted by contentious environmental issues	I genuinely feel sorry for nature (e.g., wildlife, plants, and rivers) that suffers because of how environmental problems are managed.	0.75/0.43	6 (b), 2 (a–d)	92, 6, 2	0.74/0.42	0	100, 0, 0
Compassion for people impacted by contentious environmental issues	I believe we have to take care of (e.g., provide money for) people who suffer because of how environmental problems are managed.		5 (item b)	93, 5, 2	0.62/0.29	0	97, 0, 3
Pro-environmental intent	I am willing to donate money toward an environmental cause.	0.76/0.31		93, 5, 2	0.85/0.49	0	97, 0, 3

available to clarify any questions the students may have (see Table 1). Furthermore, the students were asked to report any difficulties (e.g., struggling to understand wording of items) they encountered when responding to the SEEDSII items. If a student reported difficulties the lead researcher clarified what the SEEDSII items were conveying while taking care to not influence the student's response. Each SEEDSII was numbered prior to administration, and at the post-SSI instruction administration included a 10-dollar participant incentive in an attached unmarked envelope. The students were informed that they had the option of keeping the incentive, or donating it to a Yellowstone environmental organization through relinquishing the 10-dollars after completing the survey. To minimize coercion and prevent donation theft, donating occurred at a location separate from the assessment site monitored only by one chaperoning teacher who was hidden from students' view, and the students were told that the donations would remain anonymous. However, the serial numbers of each 10-dollar bill, and the number of the SEEDSII to which it was attached, had been recorded prior to administration. This allowed determining the association between the students' pro-environmental action and their views expressed through their SEEDSII responses. Finally, field notes and student discussions were also recorded throughout the place-based SSI instruction. While these were not systematically analyzed for this investigation, they served as auxiliary triangulating data sources of the students' SEEDSII responses. The institutional review board (IRB) at the author's university reviewed and approved all study procedures to include the use of monetary incentives and donating behaviors as a data source (IRB, project number 2005449). The students' names on data sources were replaced with pseudonyms to ensure anonymity.

3.5 | Data coding, efficacy, and analysis

In accordance with triangulated mixed-methodologies, SEEDSII Likert, and qualitative data were validated, confirmed, and analyzed through multistep and parallel processes to generate robust findings about how the place-based SSI instruction focused on the contentious environmental issue of wolf reintroduction in the Greater Yellowstone Area impacted the students': (i) NOS views; (ii) compassion toward nature and people impacted by contentious environmental issues; and (iii) pro-environmental intent. The data were also analyzed to determine potential differences that occurred along these three dimensions between donating and nondonating students. The SEEDSII presents content and questions about trophic cascades and food webs, but the analysis and reporting of the students' responses to these items falls outside the scope of this investigation. These items did however provide context for the students to respond to the SEEDSII items analyzed here. The data coding, efficacy, and analysis is presented chronologically below.

3.5.1 | Coding and scoring of SEEDSII responses

Numerical scores were attributed to the students' Likert responses ranging from "0" (e.g., inaccurate NOS views, insensitivity toward people and nature, or no pro-environmental intent) to "4" (e.g., accurate NOS views, compassionate toward people and nature, or high pro-environmental intent). A mean score was then calculated across the items for each SEEDSII dimension.

The students' SEEDSII qualitative written responses were independently coded through the use of open, axial, and pattern coding procedures by the author and a secondary coder, both of whom are science education faculty members, SSI and NOS researchers, and former secondary science teachers (Strauss & Corbin, 1998). The data sets were blinded and organized in a manner that would occlude whether the responses were completed by donating or nondonating students and before or after the place-based SSI instruction. Coding procedures consisted of: (i) establishing the level of congruence between each participant's Likert and written responses; (ii) creating provisional qualitative taxonomies congruent with the SEEDSII Likert prompts; and (iii) score attribution for the content and context of the participants' written responses to each SEEDSII dimension.

Each participant's written responses were coded as "congruent," "incongruent," or "ambiguous" based on the extent they exhibited parallel positions with the participant's Likert choices to each SEEDSII dimension. Score attribution for the content and contextualization characteristics of each participant's SEEDSII written responses began with establishing provisional qualitative taxonomies aligned with the SEEDSII Likert prompts. These provisional taxonomies and their descriptive features were then refined through multiple reviews of the written data until they accurately and substantively represented the SEEDSII dimensions and accounted for the variance of the students' responses to those dimensions. The coders utilized this final coding scheme to independently score the students' written responses.

Table 3 provides an abbreviated scoring scheme with exemplars that was used to rate the content and context of the participants' written responses to each SEEDSII dimension (see Appendix SB for the full coding scheme). The students' written responses to each SEEDSII dimension were scored along a 0–4 point scale based on the extent those responses: (i) demonstrated accurate NOS views with credible examples; (ii) extended compassion for specified others (people or nature) that are impacted by contentious environmental issues; and (iii) expressed pro-environmental intent (i.e., willingness to act) with specific actions. The initial and second rounds of independent coding respectively resulted in an 85% and a 95% inter-rater match for all items. The two coders discussed the remaining discrepancies until an agreed upon rating was determined and justified.

3.5.2 | SEEDSII data efficacy

Table 2 shows that for each SEEDSII dimension Cronbach's alphas and mean inter-item correlations respectively range from 0.61 to 0.85 and 0.28 to 0.56, thus indicating satisfactory internal consistency among Likert item responses. Mean inter-item correlations are emphasized here with a minimum threshold of 0.15 because they provide better estimates of internal consistency than Cronbach's alpha when scales consist of fewer than ten items (see Briggs & Cheek, 1986; Clark & Watson, 1995). Between zero and six percent of the students expressed confusion with the individually considered SEEDSII dimensions completed pre SSI instruction (Table 2). Zero percent of the participants indicated experiencing such struggles when completing the post SSI instruction SEEDSII. The students' SEEDSII Likert and written responses were highly congruent with 91–100% of those responses exhibiting agreement.

3.5.3 | Statistical analysis of SEEDSII Likert responses

Assuming the mean scores derived from the Likert responses for each SEEDSII dimension approximate an interval scale (see Carifio & Perla, 2008; Norman, 2010), a mixed within-between analysis of variance (ANOVA) was used to determine if: (i) these scores significantly changed from before to after the place-based SSI instruction, and (ii) the change of these scores was significantly different between donating and nondonating students. A one-way ANOVA was also conducted to compare the donating students' and nondonating students' SEEDSII dimension Likert scores at the time of donating (i.e., at the post SSI instruction SEEDSII administration). This determined the extent that the students' pro-environmental donating action, at the time it was enacted, was associated with their NOS views, compassion toward nature and people impacted by contentious environmental issues, and pro-environmental intent. To provide baseline comparisons, a one-way ANOVA was conducted on these

TABLE 3 Abbreviated scoring scheme with students' quotes serving as exemplars for the SEEDSII NOS, compassion, and pro-environmental intent dimensions (see Appendix B for the full scoring scheme)

Nature of scientific theories such as trophic cascade	Anchor points	Scientific theories will not change, or will change because they are "just theories" and become laws.	Will change due to new information/evidence with little explanation. Or, are proven if based on experiments but can typically change.		Will change due to new information and reinterpretation of evidence.	
	Exemplar quotes	Many theories are just educated guesses.	Evidence can prove multiple things so people can interpret it in many different ways, which can cause theories to change.	Theories are things that we have evidence for, but aren't 100% sure about. Like the theory of relativity or the big bang.	Scientific theories are ideas and can change and must be further tested. Scientific theories can be proven wrong because evidence is found and scientists can reinterpret evidence in their own ways.	Scientific theories are never truly proven because they are altered by new evidence and different interpretations of currently used evidence. For example, the trophic cascade was thought to only be top-bottom or bottom-top, but it actually might be from the middle out.
	Score	**0 = apathetic toward nature or people**	**1 = general caring toward nature or people (no reference)**	**2 = general caring toward nature or people (with reference)**	**3 = deep compassion toward nature or people (no reference)**	**4 = deep compassion toward nature or people (with reference)**
Compassion for those impacted by contentious environmental issues	Anchor points	Caring for nature impacted by contentious environmental issues absent.	Generic and sometimes perfunctory care for nature impacted by contentious environmental issues. Oftentimes exhibit diffusion of responsibility (e.g., "we statements").		Deep levels of genuine care for nature impacted by contentious environmental issues. Oftentimes exhibit personal feelings of responsibility (e.g., "I statements").	

(Continues)

TABLE 3 (Continued)

	Score	0 = apathetic toward nature or people	1 = general caring toward nature or people (no reference)	2 = general caring toward nature or people (with reference)	3 = deep compassion toward nature or people (no reference)	4 = deep compassion toward nature or people (with reference)
	Exemplar quotes	I cannot feel sorry for a non-human "entity." Entity is in quotes because we think of nature as a living thing, even though it is just a human concept.	I think that we should help nature that is suffering because of our managing environmental problems because nature influences us.	What we do in nature is very important. If we don't take care of nature things like what happened with the wolf will happen again.	I feel sorry for nature when it suffers because nature shouldn't have to suffer because of the decisions of humans. I also feel like as humans living with nature that it is our experience when nature suffers.	When we don't put ourselves in animals' shoes we can't make a good decision. When Aldo Leopold killed a wolf he changed views. I feel we all need to feel empathy like he did.
	Score	**0 = unwilling/low willingness**	**1 = moderately willing (no specific action)**	**2 = moderately willing (with specified action)**	**3 = highly willing (no specific action)**	**4 = highly willing (with specified action)**
Pro-environmental intent	Anchor points	Pro-environmental intent is largely absent.	Willingness to commit to actions that if specified collectively require little to moderate personal investment.		Willingness to commit to actions that if specified collectively require significant personal investment.	
	Exemplar quotes	I wouldn't do much for [or in] the environment unless it's with soccer.	We can all do little things and when we do all the little things will add up to a great total.	Recycling is a good and easy way to help with environmental problems and if everyone does that it will help the world a lot.	After this trip and seeing nature at its fullest definitely strengthened my relationship with nature and I definitely would be willing to do almost anything if it helps nature.	We don't really need electronics. I would be in a nature club and raise funds to help the environment and definitely persuade others that the environment is special and important. I already got out of my way to recycle and I will walk or bike anywhere.

two groups' pre SSI instruction SEEDSII dimension Likert scores. Effect size calculation and interpretation followed Cohen (1988) for parametric ANOVA (η^2: .01= small, .06 = moderate, and .14 = large effect).

3.5.4 | Statistical analysis of SEEDSII qualitative written responses

Nonparametric tests were used to analyze the students' SEEDSII qualitative scores because of that data's clear ordinal nature (Conover, 1999). These analyses paralleled the parametric approaches described above. Wilcoxon signed-rank tests determined if the students' written response scores for each SEEDSII dimension significantly changed through the place-based SSI instruction focused on wolf reintroduction. Mann–Whitney *U* tests were then conducted on the gains in these scores across donating and nondonating students. Mann–Whitney *U* tests were also used to compare donating students' and nondonating students' SEEDSII written response scores at the time of donating. Mann–Whitney *U* tests provided baseline comparisons of these two groups' pre SSI instruction SEEDSII written response scores. Effect size calculation and interpretation followed Cohen (1988) for nonparametric tests (r: .1 = small, .3 = moderate, and .5 = large effect).

4 | RESULTS

Presented below in three sections arranged according to the order of this investigation's research questions are detailed results derived from the analysis of the students' SEEDSII Likert and written responses. The sections respectively address the students' responses about the: (i) five NOS dimensions related to investigating and resolving contentious environmental issues; (ii) two dimensions regarding compassion toward people and nature impacted by contentious environmental issues; and (iii) one dimension addressing pro-environmental intentions. Within each section, presented first are quantitative results with supporting illustrative exemplars of the students' written responses that show how the students' views about each of the SEEDSII dimensions were impacted through the place-based SSI instruction focused on wolf reintroduction. Presented next are results comparing how donating ($n = 22$) and nondonating ($n = 38$) students' SEEDSII responses changed through the SSI instruction and differed when donating.

Tables 4–6 present significance testing and distributions regarding how the SEEDSII Likert and written responses of all students, and the subgroups of donating and nondonating students, changed from before to after the place-based SSI instruction. Tables 7 and 8 present significance testing regarding how the SEEDSII Likert and written responses from donating and nondonating students compared before the place-based SSI instruction, and at the time of donating. To aid interpretation, Table 3 and Appendix SB present the scoring scheme used to analyze the students' SEEDSII written responses. Appendix SC presents the mixed-within between plots showing the change in donating and nondonating students' Likert scores.

4.1 | RQ1. How are students' NOS views impacted through place-based SSI instruction; and how are those views associated with enacted pro-environmental action?

Tables 4–6 demonstrate that the students' responses exhibited copious misconceptions across all five of the SEEDSII NOS dimensions prior to the place-based SSI instruction. Through that instruction the students' NOS views became significantly more accurate and contextualized. Considered separately, donating students' views about several NOS dimensions became significantly more accurate and

TABLE 4 Mixed within-between ANOVA results comparing the change in all students' ($n = 60$), and the change of donating ($n = 22$) and nondonating ($n = 38$) students', SEEDSII Likert response scores from before (pre) to after (post) the place-based SSI instruction

		Pre mean (*SD*)	Post mean (*SD*)	Comparison	*F* (1, 58)	*p*	n^2
Methodology of environmental science investigations	All	1.65 (0.75)	3.10 (0.63)	Δ in all students' scores	148.6	<.001	.72
	Not donate	1.60 (0.71)	2.99 (0.59)	Δ in donators' versus Δ in nondonators' scores	0.69	.41	.01
	Donate	1.73 (0.83)	3.31 (.66)				
	Not donate	2.93 (0.54)	3.10 (0.53)	Δ in donators' versus Δ in nondonators' scores	10.8	.002	.16
	Donate	2.86 (0.72)	3.52 (0.45)				
Scientific observation/interpretation of nature	All	3.32 (0.52)	3.46 (0.48)	Δ in all students' scores	7.2	.009	.11
	Not donate	3.30 (0.49)	3.33 (0.49)	Δ in donators' versus Δ in nondonators' scores	5.3	.02	.08
	Donate	3.34 (0.59)	3.69 (0.39)				
Role of science and technology for solving environmental issues	All	2.47 (0.66)	2.89 (0.56)	Δ in all students' scores	24.5	<.001	.30
	Not donate	2.32 (0.66)	2.69 (0.44)	Δ in donators' versus Δ in nondonators' scores	0.42	.52	.01
	Donate	2.73 (0.57)	3.22 (0.59)				

(Continues)

TABLE 4 (Continued)

		Pre mean (*SD*)	Post mean (*SD*)	Comparison	F (1, 58)	p	η^2
Cultural influences on environmental science and its use	All	2.05 (0.83)	2.55 (0.70)	Δ in all students' scores	18.8	<.001	.24
	Not donate	2.06 (0.79)	2.44 (0.69)	Δ in donators' versus Δ in nondonators' scores	1.7	.20	.03
	Donate	2.03 (0.91)	2.73 (0.68)				
Compassion for nature impacted by contentious environmental issues	All	2.79 (0.70)	2.95 (0.64)	Δ in all students' scores	4.4	.04	.07
	Not donate	2.77 (0.72)	2.80 (0.63)	Δ in donators' versus Δ in nondonators' scores	3.2	.08	.05
	Donate	2.82 (0.68)	3.21 (0.58)				
Compassion for people impacted by contentious environmental issues	All	2.69 (0.58)	2.64 (0.59)	Δ in all students' scores	0.06	.82	.001
	Not donate	2.64 (0.65)	2.51 (0.51)	Δ in donators' versus Δ in nondonators' scores	1.65	.20	.03
	Donate	2.78 (0.45)	2.86 (0.67)				
Pro-environmental intent	All	2.87 (0.55)	2.82 (0.60)	Δ in all students' scores	0	.99	<.001
	Not donate	2.82 (0.55)	2.60 (0.53)	Δ in donators' versus Δ in nondonators' scores	9.1	.004	.14
	Donate	2.97 (0.54)	3.20 (0.51)				

TABLE 5 Wilcoxon-rank sum results comparing the change in all students' ($n = 60$), and Mann–Whintey *U* test results comparing the gains of donating ($n = 22$) and nondonating ($n = 38$) students', SEEDSII written response scores from before (pre) to after (post) the place-based SSI instruction

	Group level	Pre median	Post median	Comparison	*Z*	*p*	*r*
Methodology of environmental science investigations	All	0	2.0	Δ in all students' scores	−5.6	<.001	.72
	Not donate	0	2.0	donators' versus nondonators' gain scores	−1.3	.21	.18
	Donate	0	3.0				
	Not donate	1.0	1.0	donators' versus nondonators' gain scores	−2.5	.01	.34
	Donate	1.0	3.0				
	Not donate	1.0	2.0	donators' versus nondonators' gain scores	−2.4	.02	.32
	Donate	1.0	3.5				
	Not donate	1.0	1.0	donators' versus nondonators' gain scores	−2.0	.05	.27
	Donate	1.0	3.0				
Cultural influences on environmental science and its use	All	0	1.0	Δ in all students' scores	−4.9	<.001	.63
	Not donate	0	1.0	donators' versus nondonators' gain scores	−1.8	.07	.25
	Donate	1.0	2.0				

(Continues)

TABLE 5 (Continued)

	Group level	Pre median	Post median	Comparison	*Z*	*p*	*r*
	Not donate	1.0	1.0	donators' versus nondonators' gain scores	−1.5	.14	.21
	Donate	1.0	2.0				
Compassion for people impacted by contentious environmental issues	All	1.0	1.0	Δ in all students' scores	−3.1	.001	.45
	Not donate	1.0	1.0	donators' versus nondonators' gain scores	−0.61	.55	.08
	Donate	1.0	1.0				
Pro-environmental intent	All	1.0	1.0	Δ in all students' scores	−3.8	<.001	.44
	Not donate	1.0	1.0	donators' versus nondonators' gain scores	−3.1	.002	.40
	Donate	1.0	2.0				

TABLE 6 Percent distribution of the classification of all ($n = 60$), donating ($n = 22$), and nondonating ($n = 38$) students' SEEDSII qualitative responses collected before (pre) and after (post) the place-based SSI instruction

			Score[a]				
	Group level	**Time**	**0**	**1**	**2**	**3**	**4**
Methodology of environmental science investigations	All	Pre	64	28	6	0	2
		Post	8	35	8	12	37
	Not donate	Pre	60	34	6	0	0
		Post	10	37	8	11	34
	Donate	Pre	72	17	6	0	5
		Post	4	32	9	14	41
		Post	23	25	23	2	27
	Not donate	Pre	37	40	23	0	0
		Post	32	26	26	3	13
	Donate	Pre	25	45	25	5	0
		Post	9	23	18	0	50
Scientific observations of nature	All	Pre	0	84	13	3	0
		Post	0	38	25	7	30
	Not donate	Pre	0	80	17	3	0
		Post	0	45	29	8	18
	Donate	Pre	0	90	5	5	0
		Post	0	27	18	5	50
Role of science and technology for solving environmental issues	All	Pre	15	75	5	5	0
		Post	3	41	16	9	31
	Not donate	Pre	20	69	3	8	0
		Post	6	47	25	0	22
	Donate	Pre	5	85	10	0	0
		Post	0	32	0	23	45

(Continues)

TABLE 6 (Continued)

	Group level	Time	Score[a] 0	1	2	3	4
Cultural influences on environmental science and its use	All	Pre	52	46	0	2	0
		Post	19	38	28	0	15
	Not donate	Pre	56	41	0	3	0
		Post	27	38	24	0	11
	Donate	Pre	45	55	0	0	0
		Post	5	38	33	0	24
		Post	10	45	19	9	17
	Not donate	Pre	12	73	9	6	0
		Post	16	46	22	8	8
	Donate	Pre	11	56	0	28	5
		Post	0	43	14	10	33
Compassion toward people impacted by contentious environmental issues	All	Pre	29	62	5	2	2
		Post	24	38	21	8	9
	Not donate	Pre	37	57	0	3	3
		Post	30	38	19	8	5
	Donate	Pre	15	70	15	0	0
		Post	14	38	24	10	14
Pro-environmental intent	All	Pre	32	53	15	0	0
		Post	20	37	29	7	7
	Not donate	Pre	40	42	18	0	0
		Post	29	39	29	0	3
	Donate	Pre	19	71	10	0	0
		Post	5	36	27	18	14

[a]See scoring categories presented in Table 3 and Appendix B.

TABLE 7 ANOVA results comparing donating ($n = 22$) and nondonating ($n = 38$) students' SEEDSII Likert response scores collected before the place-based SSI instruction, and after the place-based SSI instruction at the time of donating

Dimension	Comparison	F (1, 58)	p	η_2
	Post scores	4.0	.05	.06
	Post scores	10.0	.003	.15
	Post scores	8.9	.004	.14
	Post scores	15.6	<.001	.21
	Post scores	2.6	.11	.04
	Post scores	6.3	.02	.10
	Post scores	5.2	.03	.08
Pro-environmental intent	Pre scores	1.1	.29	<.01
	Post scores	17.9	<.001	.24

contextualized when compared to nondonating students through the place-based SSI learning experience. Furthermore, donating students' NOS views were significantly more accurate and contextualized than nondonating students when the donating action occurred (Tables 7 and 8). Detailed results are presented below regarding how the students' views changed across each NOS dimension, and how the NOS views of donating and nondonating students compared.

4.1.1 | Methodology of environmental science investigations

The majority of the students entered the place-based SSI instruction wrongly thinking set scientific methods and controlled experiments were the only valid forms of environmental science investigation. However, these views as measured by the students' Likert responses changed and significantly improved, with a large effect attributed to their SSI learning experiences, to those recognizing that scientists employ many valid investigative methods ($p < .001$; $\eta^2 = .72$; Table 4). Congruently, the place-based SSI instruction had a large significant impact on the accuracy and contextual nature of the students written views about scientists' methods ($p < .001$; $r = .72$; Table 5). Table 6 shows that the proportion of students inaccurately (score = 0) claiming that all scientists followed the same experimental method fell from 64 to 8%, and those demonstrating some merit (scores = 1 and 2) increased 9%, through the place-based SSI instruction. Furthermore, the proportion of students providing accurate (scores = 3 and 4) responses about environmental science methodologies improved from 2 to 49% through the place-based SSI instruction; and 35% more of the students' statements reflected themes and examples addressed during that instruction (score = 4).

TABLE 8 Mann–Whitney *U* test results comparing donating ($n = 22$) and nondonating ($n = 38$) students' SEEDSII written response scores collected before the place-based SSI instruction, and after the place-based SSI instruction at the time of donating

Dimension	Comparison	*Z*	*p*	*r*
	Post scores	−0.85	.41	.11
	Post scores	−2.8	.005	.36
	Post scores	−2.1	.03	.28
	Post scores	−2.3	.02	.32
	Post scores	−2.1	.03	.28
	Post scores	−2.3	.02	.31
	Post scores	−1.5	.14	.20
Pro-environmental intent	Pre scores	−0.79	.43	.10
	Post scores	3.0	.003	.38

Steve's written responses below exemplify how the students developed more informed contextualized views about the nature of environmental science methodologies. His pre SSI instruction response indicates he wrongly thought that science must proceed via set controlled methods.

> The scientific method must be followed in order for results to be published, and the scientific method applies to all aspects of science. If an experiment is not controlled, it is void. *Steve pre SSI instruction (score = 0)*

Like many students, Steve's later response below accurately reflects the SSI instructional experiences such as field discussions with wolf ecologists about how competing research groups used varying approaches to account for how wolf reintroduction is impacting the Greater Yellowstone Ecosystem.

> With the wolves and aspen in Yellowstone, no scientific method was used; experiments were not conducted in a controlled environment. Based on observations however, knowledge was still gained about ecology. *Steve post SSI instruction (score = 4)*

4.1.2 | Nature of scientific theories such as trophic Cascade

The SSI instruction focused on the contentious environmental issue of wolf reintroduction had a significantly large and positive impact on the accuracy of the students' Likert positions about the nature of scientific theories ($p < .001$, $\eta^2 = .34$; Table 4). The students' written responses about the nature of scientific theories also demonstrated significantly large improvements in accuracy and contextualization through the place-based SSI instruction ($p < .001$, $r = .50$; Table 5). Through that instruction, the proportion of students expressing inaccurate (score = 0) written notions about scientific theories (e.g., theories are "just simple ideas" akin to guesses that can quickly change because of token evidence) reduced from 33 to 23%. Also, the proportion of students' written responses about scientific theories that demonstrated some merit (scores = 1 and 2), but were often conflicted (e.g., that theories can change until firmly proven through experiments), fell from 65 to 48%. Prior to the SSI instruction, 2% of the students' responses about scientific theories at best were accurate with no contextualizing (score = 3). However, after the place-based SSI instruction, 27% more of the students better expressed the complexity of theories through fully accurate and contextualized responses that reflected the SSI instructional themes (score = 4).

Hallie's written responses below provide an illustrative example of how the students' developed more accurate and contextualized views about the nature of scientific theories through the place-based SSI instruction. Her pre SSI instruction views lacked context and indicated hedging between the ideas that theories may be built upon and that theories established by well-run experiments will not change.

> Scientific theories that are based on well-run experiments are proven, but I'm not sure about them ever changing. Scientists can always build on old theories with new information and ideas. *Hallie pre SSI instruction (score = 1)*

Her later views drew from readings and discussions addressed during the place-based SSI instruction, which point out that while some research firmly supports the top–down trophic cascade account (e.g., Paine's, 1966 predatory starfish research), current research in Yellowstone challenges those theoretical assumptions (Kauffman, Brodie, & Jules, 2013; Marris, 2014).

> There are many investigations that support trophic cascade theory. However, it is not as simple as it seems and excludes many important variables that could affect how trophic cascades work (such as drought and floods). Because of this trophic cascade may be further investigated, built upon, and very likely changed. *Hallie post SSI instruction (score = 4)*

4.1.3 | Scientific observations and interpretations of nature

The students' Likert measured views about scientists' observations of and interpretations about nature became significantly more informed, in a moderately large part, through the place-based SSI instruction focused on wolf reintroduction ($p = .009$, $\eta^2 = .11$; Table 4). That instruction also resulted in significantly large impacts on the accuracy and contextual nature of the students' written responses about this NOS dimension ($p < .001$, $r = .60$; Table 5). Prior to and after completing the place-based SSI instruction none of the students' written responses about scientists' observations and interpretations were fully inaccurate (score = 0; Table 6). However, 97% of the students' pre SSI instruction written responses had some merit (scores = 1 and 2) primarily because while they claimed that scientists' observations should not vary and their disagreements were akin to differing personal conjectures, they also explained that scientists could generate different interpretations. The remaining students' pre SSI instruction responses about scientists' observations and interpretations were accurate with no contextualizing examples (score = 3). After the SSI learning experience, approximately one-third of the students provided fully accurate and contextual recognition about how the variance in scientists' observations and interpretations is a normal and important part of valid scientific inquiry (score = 3 and 4).

Jack's written responses below demonstrate how many of the students' notions about scientists' observations and interpretations changed through the place-based SSI instruction. Initially, Jack superficially claimed that varying scientific observations are a simply a matter of people having different perceptions, with no reference to scientists' interpretations.

> Everyone has a different perception and different observations. Just because one person saw something doesn't mean that's how it always is. *Jack pre SSI instruction (score = 1)*

Jack's post SSI instruction descriptions reflected field instruction where the wolf ecologists showed, and discussions and readings explained, how scientists were researching the same Yellowstone landscape, but developed varied observations and competing accounts about how wolves impacted that landscape.

> Beschta and Kauffman both researched to determine the effect of the wolf population on aspen, but they got different results and interpreted them differently. That doesn't mean they were wrong, it means they observed differently. *Jack post SSI instruction (score = 4)*

4.1.4 | Role of science and technology for solving environmental problems

The place-based SSI instruction had a significantly large impact on the accuracy and contextualization of the students' positions about the role that science and technology plays for contentious environmental issues resolution (Likert: $p < .001$, $\eta^2 = .30$; written: $p < .001$, $r = .59$; Tables 4 and 5). Prior to that instruction, many students' responses demonstrated naïve views resembling "scientism," where science and technology are endowed an excessive privileged status over other considerations (e.g., culture) for rectifying contentious environmental issues. After the SSI instruction, a greater proportion of the students' responses demonstrated more balanced, informed, and contextualized views that advocated science along with other specified factors (e.g., sociocultural, economic, and ethical) must be weighed when resolving contentious environmental issues.

Focusing more specifically on how the students' written responses changed from before to after the place-based SSI course, the proportion of the students who indicated that science and technology should solely resolve contentious environmental issues (score = 0) reduced from 15 to 3%. Furthermore, the proportion of students tepidly and generically indicating that factors (e.g., others' opinions) beyond science and technology should play role in contentious environmental issues resolution (scores = 1 and 2) fell from 80 to 57%. Prior to the place-based SSI instruction, 5% of the students' written responses at best noted significant yet generically described factors (e.g., culture, score = 3), which could be considered when resolving contentious environmental issues. After that instruction, 9% of the students provided such responses; and 31% more of the students' accurately provided contextualized examples reflecting SSI instructional experiences such as analyzing and discussing media that addressed how historical (the cruel extirpation of wolves), economic (e.g., how wolves attract tourism), and cultural (e.g., ranchers' and Native Americans' perspectives on wolves) considerations are an integral part of resolving contentious environmental issues (score = 4).

Mary's quotes below exemplify how the students better understood through the place-based SSI instruction that science along with several other considerations should inform how contentious environmental issues are resolved. Her pre SSI instruction written position advocates that science alone should fix contentious environmental issues.

I think that science is the only real way to prove things, so it can solve our problems. *Mary pre-SSI instruction (score = 0)*

Her post SSI instruction statement draws from themes addressed during SSI instructional activities (e.g., videos and discussions about ranchers coping with wolf reintroduction) to describe more accurately how cultural considerations play as an important role as science for resolving contentious environmental issues.

With environmental issues, culture is just as important of a consideration as science is. For example, the wolf debate with the ranchers - they live in a culture where wolves are hated because they kill livestock. With environmental issues, it is important to please both groups, culturally and scientifically. *Mary post SSI instruction (score = 4)*

4.1.5 | Cultural influences on how environmental science is conducted and used

The students' views about how culture influences the way environmental science is conducted and implemented were significantly impacted, with large effect, through the place-based SSI instruction focused on wolf reintroduction (Likert: $p < .001$, $\eta^2 = .24$; written: $p < .001$, $r = .63$; Tables 4 and 5). More specifically, the students' expressed views changed to better illustrate, particularly through contextualized written responses, that cultural considerations should influence how environmental science research is conducted and used.

Closer inspection of the students' written responses reveals that the proportion of students wrongly thinking that culture should not influence how environmental science is conducted and used (score = 0) fell from 52 to 19% through the place-based SSI instruction (Table 6). The proportion of students who provided views demonstrating some merit (scores = 1 and 2, e.g., culture should influence how science is used but not conducted) increased from 46 to 66% from before to after the SSI instruction. Notably the proportion of students providing contextualizing examples through their responses demonstrating some merit (score = 2) increased 28% over this time period. Lastly, the proportion of students rightly indicating through their written responses that culture should influence how science is conducted and used increased from 3%, who provided no contextualizing examples (score = 3), to 15%, who provided contextualizing examples (score = 4), through the place-based SSI instruction.

Mike's written statements below reflect the dramatic shift in thinking that many students experienced through the SSI instruction regarding how culture could influence science. Mike's initial and naïve pre SSI instruction position was that in no ways should culture influence science.

Culture should not influence science. *Mike pre SSI instruction (score = 0)*

Mike's later views reflect the SSI instructional experiences, such as discussions with the wolf ecologists who conducted outreach with ranchers, to advocate that the ranchers' culture should influence how wolves are researched and managed in Yellowstone.

Culture, like the ranchers whose culture is to kill any wolf that comes near their cattle, should have a role in investigating environmental problems so scientists can see both sides of the problem. *Mike post SSI instruction (score = 4)*

4.1.6 | NOS views and pro-environmental action

At the onset of the place-based SSI instruction, the donating students demonstrated similar NOS views to their nondonating counterparts; with the only exception being that the donating students' Likert scores measuring their views about the role of science and technology for resolving contentious environmental issues being somewhat significantly higher (Tables 7 and 8; $p = .02$, $\eta^2 = .09$). Significant differences were demonstrated, with a moderate to large degree of variance, between donating and non-donating students regarding the magnitude to which each group developed and expressed their NOS views through the place-based SSI instruction. Tables 4 and 5 show that the donating students demonstrated significantly higher gains in their response scores measuring their views about the nature of scientific theories (Likert: $p = .002$, $\eta^2 = .16$; written: $p = .01$, $r = .34$); scientists' observations of and interpretations about nature (Likert: $p = .02$, $\eta^2 = .08$; written: $p = .02$, $r = .32$), and the role of science and technology for contentious environmental issues resolution (written only: $p = .05$, $r = .27$) than nondonating students. Further considering the change in students' written responses across these three NOS dimensions, the change in donating students' inaccurate views (score = 0) decreased up to 16% (Table 6). Whereas, the proportion of their accurate responses without (score = 3) and with contextualizing examples (score = 4) increased up to 68% from before to after the place based SSI instruction. Conversely, the proportion of nondonating students' inaccurate responses (score = 0) decreased up to 14% and the proportion of their accurate responses without (score = 3) and with contextualizing examples (score = 4) increased up to 26% through the SSI instruction.

The donating students' NOS views, at the time of donating, were significantly more accurate and contextualized than non-donating students. Tables 7 and 8 show that significant differences occurred, with a moderate to large degree of variance, between these two groups' response scores across the dimensions of environmental science methodologies (Likert only: $p = .05$, $\eta^2 = .06$), nature of scientific theories (Likert: $p = .003$, $\eta^2 = .15$; written: $p = .005$, $r = .36$), scientists' observations of and interpretations about nature (Likert: $p = .004$, $\eta^2 = .14$; written: $p = .03$, $r = .28$), the role that science and technology play for contentious environmental issues resolution (Likert: $p = .001$, $\eta^2 = .21$; written: $p = .02$, $r = .32$), and how culture influences environmental science research and implementation (written only: $p = .03$, $r = .28$). Across the latter four NOS dimensions, the proportion of inaccurate (score = 0) written responses respectively provided by donating and nondonating students ranged from 0 to 9% and from 0 to 32% at the time of donating. The proportion of somewhat merited (scores 1 and 2) written responses respectively provided by donating and non-donating students ranged from 32 to 71% and 52 to 74%. Finally, at the time of donating, the proportion of accurate (scores 3 and 4) written responses respectively provided by donating and nondonating students ranged from 24 to 68% and 11 to 26%.

4.2 | RQ 2. How are students' compassion toward humans and nature impacted through place-based SSI instruction; and how is that compassion associated with pro-environmental action?

In comparison to their shifts in NOS understanding through the place-based SSI instruction focused on the contentious topic of wolf reintroduction, the students exhibited lesser gains in their compassion for nature and people impacted by contentious environmental issues (Tables 4–6). However, Tables 7 and 8 show that donating students exhibited significantly higher degrees of compassion toward nature and people impacted by contentious environmental issues than nondonating students at the time of donating. Presented below are detailed results regarding the change in students' compassion for nature and people through the place-based SSI course, and how that compassion differed between donating and nondonating students.

4.2.1 | Compassion toward nature impacted by contentious environmental issues

Tables 4 and 5 show that the place-based SSI instruction had a significant and moderate effect on the extent that the students expressed and contextualized compassion toward nature that is impacted by contentious environmental issues (Likert: $p = .04$, $\eta^2 = .07$; written: $p = .02$, $r = .29$). These trends are further revealed through a closer examination of the place-based SSI instruction's impact on the students' written responses (Table 6). The proportion of students expressing apathy (pre—12%, post—10%, score = 0), general caring (pre—67%, post—64%, scores = 1 and 2), and deep compassion (pre—21%, post—26%, scores 3 and 4) toward nature remained relatively stable from before to after the place-based SSI instruction. However, the contextual features of the students' statements of general caring and deep compassion for nature varied significantly from before to after the SSI instruction. All of the students' expressions of general care for nature pre SSI instruction were generic (score = 1) and typically advocated that nature should be conserved for its instrumental value (e.g., human use). Of the 21% of the students' whose pre-SSI instruction responses indicated deep compassion for nature, only 6% to provided reference to a specified natural entity (e.g., trees, animals, score = 4). After the SSI instruction, 19% (score = 3) and 17% (score = 4) of the students respectively provided expressions of general care and deep compassion through referring to specifically identified natural entities that suffer because of contentious environmental issues. James' initial views reflect many students' pre SSI instruction expressions of general care for nature that were nondescript and somewhat detached.

> We should be able to help nature but should not get too carried away. *James pre SSI instruction (score = 1)*

James' shift in his compassion for nature exemplifies how a greater proportion of students after the SSI instruction expressed deep compassion for specifically identified natural entities that suffer because of contentious environmental issues. Moreover, his quote below reflects the experiential facets of the SSI instruction such as the students engaging in wildlife watching and hiking while discussing readings (e.g., Leopold's "Thinking Like a Mountain") that address the moral and empathetic aspects of environmental stewardship.

> We should take care of suffering nature because we caused it to suffer. I feel bad for nature. Like when wolves get shot I feel horrible. *James post SSI instruction (score = 4)*

4.2.2 | Compassion toward people impacted by contentious environmental issues

The students' Likert scores measuring their compassion toward people impacted by contentious environmental issues demonstrated insignificant changes from before to after the place-based SSI instruction focused on wolf reintroduction (Table 4). However, the students' written responses exhibited significantly higher degrees of compassion toward people impacted by contentious environmental issues, in moderate part, due to completing the SSI instruction (Table 5; $p = .003$, $r = .38$). Further inspection of this significant finding demonstrates that students expressing apathy (pre—29%, post—24%, score = 0) toward people changed little through the place-based SSI instruction (Table 6). However, the proportion of students expressing general care without referring to specific people (score = 1) decreased from 62 to 38%; and the proportion of students expressing general care through referring to specific people (pre—5%, post—21%, score = 2), and deep compassion without (pre—2%, post—8%, score = 3) and with (pre—2%, post—9%, score = 4) referring to specific people markedly increased through the SSI instruction. For instance, Rachel's pre-SSI learning experience written response indicates a general care for unspecified groups of people impacted by environmental problems.

> I believe that it is important to help those affected by the environment because, in some way, it is probably our fault that they are having these problems. *Rachel pre SSI instruction (score = 1)*

After completing the SSI instruction, Rachel demonstrated genuine concern for specifically identified groups (e.g., ranchers) that are impacted by the Yellowstone wolf reintroduction issue.

> It is important to consider all sides with issues like this. In the rancher/wolf debate, I tend to side with the preservationists because I don't think that wolves should be killed. However, cows cost a lot, and if they are killed, that is a big loss to the ranchers. *Rachel post SSI instruction (score = 4)*

4.2.3 | Compassion for nature and people and pro-environmental action

At the onset of the place-based SSI learning experience focused on wolf reintroduction, the donating and nondonating students demonstrated statistically similar degrees of compassion toward people and nature that are impacted by contentious environmental issues (Tables 7 and 8). Furthermore, extent that these two groups' compassion toward people and nature changed through the SSI learning experience was also statistically similar (Tables 4 and 5).

Tables 7 and 8 show at the time of donating, donating students' demonstrated significantly higher degrees of compassion with more references toward specified natural entities impacted by contentious environmental issues than their nondonating counterparts' (Likert: $p < .02$, $\eta^2 = .10$, written: $p < .02$, $r = .31$). The respective proportions of donating and nondonating students' written responses demonstrating apathy toward nature (score = 0) were 0 and 16%, general caring toward nature (scores = 1 and 2) were 57 and 68%, and deep compassion toward nature (scores = 3 and 4) were 43 and 16% at the time of donating. Furthermore, the donating students' Likert scores indicated they had significantly higher degrees of concern for people impacted by contentious environmental issues than the nondonating students ($p = .03$, $\eta^2 = .08$). Effect sizes indicate a moderate degree of variance existed between the donating and nondonating students' compassion for nature and people at the time of donating.

4.3 | RQ 3. How are students' pro-environmental intent impacted through place-based SSI instruction; and how is that intent associated with pro-environmental action?

The students' Likert scores measuring their pro-environmental intent demonstrated insignificant changes from before to after the place-based SSI instruction (Table 4). However, the students' written response scores regarding this dimension significantly changed, in moderate part, due to completing the SSI learning experience (Table 5; $p < .001$, $r = .44$). These changes were largely due to the students providing more concrete examples (e.g., recycling, stream clean up, raising funds for environmental causes) through their written responses about how they planned to resolve environmental issues after completing the SSI learning experience. More specifically, Table 6 shows that the proportion of students expressing unwillingness (score = 0) to resolve environmental issues decreased from 32 to 20% through the place based SSI instruction. Over this time period, the proportion of students expressing a moderate intent to take nondescript actions to resolve environmental issues (score = 1) decreased from 53 to 37%, and the proportion of students expressing the same level of intent and specifying actions that collectively require modest personal investment (score = 2) increased from 15 to 29%. The proportion of students demonstrating high levels of pro-environmental intent increased from 0 to 14% (score = 3 and 4), with half of those students explicitly describing pro-environmental actions they intended to take that collectively require significant personal investment (score = 4).

Maddie's statements below represent the more dramatic ways the students' pro-environmental intentions shifted through the place-based SSI instruction. Initially, Maddie deliberates her ability to commit to the pro-environmental action of giving up electronics.

> This probably sounds selfish, but it would be really hard to give up electronics. I could do it though, probably. *Maddie pre SSI instruction (score = 2)*

After the SSI instruction, Maddie's described pro-environmental intent appeared much stronger and was illustrated through many more actions, including some of which she had already committed while in Yellowstone.

> We don't really need electronics. I would be in a nature club and raise funds to help the environment and definitely persuade others that the environment is special and important. I already got out of my way to recycle and I will walk or bike anywhere. *Maddie post SSI instruction (score = 4)*

4.3.1 | Pro-environmental intent and pro-environmental action

Tables 7 and 8 show that donating and nondonating students entered the place-based SSI instruction with statistically similar levels of pro-environmental intent. However, donating students achieved significantly higher gains in their pro-environmental intent than their nondonating counterparts, with a moderately large effect due to their SSI learning experiences (Tables 4 and 5; Likert: $p = .004$, $\eta^2 = .14$; written: $p = .002$, $r = .40$). Further considering the change in the students' written pro-environmental intent, Table 6 shows that the proportion of donating students expressing low willingness (score = 0) and moderate willingness (scores 1 and 2) to resolve environmental issues respectively decreased 14 and 18% through the SSI instruction. Whereas, through that instruction the proportion of this group's responses demonstrating high levels (score 3 and 4) of pro-environmental intent increased from 0 to 32%. Conversely, over the same time period the proportion of nondonating students' expressing low willingness (score = 0) to resolve environmental issues decreased 11%, and the proportion of this group's responses demonstrating moderate (scores 1 and 2) and high (score 3 and 4) levels of willingness respectively increased 8 and 3%. Tables 7 and 8 show significant differences among donating and nondonating students' pro-environmental intent at the time of donating, with effect sizes indicating donating students exhibited a much stronger and more detailed reference to the pro-environmental behaviors they intended to undertake (Likert: $p < .001$, $\eta^2 = .24$; written: $p = .003$, $r = .38$). The respective proportions of donating and nondonating students' pro-environmental intent rated as low (score = 0) were 5 and 29%, moderate (scores = 1 and 2) were 63 and 68%, and high (scores = 3 and 4) were 32 and 3% at the time of donating (Table 6).

5 | DISCUSSION AND IMPLICATIONS

Promoting how to help students develop the knowledge, beliefs, and habits of mind necessary for civic and environmental engagement has been a longstanding and championed cause for science educators. Part of this effort includes helping people understand NOS so they can better engage SSI (Herman, 2015; Khishfe, 2012). While the appeals for promoting the non-normative aspects of science carry some merit, science educators must also integrate normative considerations to ensure that SSI engagement accounts for sociocultural values and perspectives and entails democratic socioscientific decision making (Herman, 2015; Hodson, 2009; Zeidler, 2016). This study achieves significance through responding to this call by demonstrating that place-based SSI instruction focused on the scientific and sociocultural features of wolf-reintroduction in Yellowstone:

1. deeply impacted the accuracy and contextual nature of secondary students' NOS views;
2. encouraged students to be more compassionate toward specified others that are negotiating contentious environmental issues; and
3. promoted students to develop increased levels of pro-environmental intent.

Moreover, unlike extant work that equates socioscientific decision making with stated positions or willingness to act, this investigation established that the students' *enacted* pro-environmental behavior was linked to their NOS views, compassion for others that are negotiating contentious environmental issues, and pro-environmental intent.

5.1 | SEEDSII

The SEEDSII was not validated through conventional means typically used for survey development such as large-scale distribution and factor analysis. However, the rigorous iterative survey development with inputs from faculty, teachers, and students and the convergent mixed-methods approach that ensured a high degree of triangulation among data sources were intentionally employed to mitigate these limitations and bolster the confirmability of the findings presented here. The SEEDSII assessment was deliberately aligned with the context of the contentious environmental issues addressed during the place-based SSI instruction, which possibly contributed to the participants' providing nuanced and example-laden responses about NOS, compassion for people and nature that are impacted by contentious environmental issues, and pro-environmental intent. On one hand, it could be argued that using context specific assessments somewhat narrows the range of responses that students will provide. On the other hand, it could also be argued that teaching students to develop and express highly accurate and contextualized accounts through using scenarios experienced in the real-world better situates them to engage SSI than employing declarative (e.g., NOS tenet-focused) and traditional instructional models (Allchin, 2011; Clough & Olson, 2008; Herman, 2015). Much room exists for exploring robust SSI and NOS instructional and assessment methods that are contextually appropriate and align with conceptual change approaches (Bell, Mulvey, & Maeng, 2016; Clough, 2006; Hodson, 2009; Karisan & Zeidler, 2017).

5.2 | Place-based SSI instruction impacts

In line with recent investigations (e.g., Khishfe, 2012, 2014; Wong et al., 2008), the findings reported here demonstrate that SSI can provide contextual access for developing more accurate NOS understandings. Prior to receiving NOS instruction in Yellowstone, the students exhibited commonly held naïve beliefs about the scientific enterprise that are often perpetuated through classroom and popular media experiences such as the notion that science must proceed through set controlled procedures (Herman, 2013; Rudolph, 2007; Zeidler et al., 2016). Significance testing and effect size calculations showed that through the place-based SSI instruction focused on wolf reintroduction the students achieved highly perceptible gains in their understanding of this and other NOS ideas such as the nature of scientific theories, observations, and interpretations.

As indicated before, providing instructional contexts that exhibit clear and purposeful relevance to students and the issues they will face is among the more pressing issues facing the science education field (Gilbert et al., 2011). A significant aspect of this investigation is how it extends beyond others that simply promote and assess declarative NOS views and facilitates students to draw from purposeful and authentic place-based learning contexts and develop NOS understandings relevant to real-world contentious environmental topics. Across all of the five NOS dimensions assessed here, the students drew from the place-based SSI instruction to more accurately describe in detail how ecologists investigate, conceptualize, debate, and resolve issues such as trophic cascade and predator management. For instance, the students' responses indicated that during the field interactions with the wolf-ecologists they had learned that controlled experiments would be an inappropriate approach for investigating wolf behavior and ecosystem dynamics, and that subjective debate was an ongoing and normal process among scientists because scientists can construct very different observations and interpretations while researching the same ecological community. The students also indicated through this investigation's measures and throughout the SSI instruction that they were thinking about how scientists must weigh normative concerns (e.g., the diverse sociocultural perspectives of ranchers and Native Americans) and non-normative considerations (e.g., scientific processes and the evidence regarding the ecological impact of wolves) when proposing natural resources management decisions. Notably, these and other findings indicate how the students' views shifted from resembling "scientism" to becoming more balanced and recognizing various cultures and perspectives should contribute to contentious environmental issues resolution. Such findings are encouraging given the belief that science and technology alone will resolve contentious environmental issues has been linked to diminished levels of environmental concern (Gifford & Nilsson, 2014).

The place-based SSI instruction appeared to be less impactful on the students' compassion for those coping with contentious environmental issues and pro-environmental intent as expressed through Likert measures. However, the SSI instruction had a significant and moderately large impact on the extent that the students qualitatively expressed sincere compassion toward groups of people or entities in nature and possible pro-environmental actions. The proportion of the students expressing general care and deep compassion toward specifically identified groups of people and natural entities increased significantly from before to after the place-based SSI instruction. A similar increase occurred with the proportion of students who provided specific examples of how they intended to help the environment.

Several (e.g., Hoffman, 2008; Kollmuss & Agyeman, 2002) have argued that peoples' likeliness to engage in pro-social behaviors (e.g., recycling, environmental advocacy) increases when they can identify the perspectives of those being harmed and plausible courses of action. This investigation lends resonance to work that clarifies how SSI instruction can be a form of sociomoral education that encourages students to develop a sense of character and empathy for others when proposing avenues toward SSI resolution (Herman et al., 2018; Lee, Chang, Choi, Kim, & Zeidler, 2012). Such educative approaches are crucial given contemporary media that work against contemplative and empathetic social discourse about technocentric solutions for SSI that impose unanticipated and unequal positive and negative impacts upon people and nature (Herman, 2013; Hodson, 2009; Turkle, 2012; Zeidler et al., 2016).

Worthy of discussion are the possible reasons why students' NOS understanding gains appeared to exceed their development of compassion for others impacted by contentious environmental issues and pro-environmental intent. First, the students began the SSI place-based instruction possessing copious NOS misconceptions, which many later conveyed was a direct result of their school science learning. Second, the chaperoning teachers indicated that many students participated on the Yellowstone trip because of their keen personal appreciation of the environment. Given the durable and complex nature of character and values (Lee et al., 2012, 2013), perhaps the students had a greater potential through the relatively short place-based SSI instruction for improving their NOS conceptions, than further developing care based social and moral perspectives as they relate to contentious environmental issues resolution. Future research should add clarifying accounts of the nuanced dynamic that plays out between cognitively and emotively oriented ways of knowing when people engage SSI under a variety of contexts.

5.3 | NOS, compassion, intentions, and actions

This investigation goes well beyond those that link NOS views to socioscientific decisions measured through written and verbal measures, which may not efficaciously gauge how people act (Gifford & Nilsson, 2014; Kormos & Gifford, 2014). Supporting this point, only 44% of the students claiming a willingness to donate to an environmental organization on the post-SSI instruction SEEDSII enacted this claim by relinquishing their 10-dollar incentive to a Yellowstone environmental organization. Notably, donating students developed and exhibited more sophisticated and contextualized NOS views and expressed higher levels of compassion for nature and people impacted by contentious environmental issues and pro-environmental intent than those who elected to keep the monetary incentive. Therefore, this investigation strongly builds upon previous work to indicate NOS views, character and values, and sociocultural considerations are associated with socioscientific decision making and action (Herman, 2015; Hodson, 2009; Lee et al., 2012, 2013).

Current theories of pro-environmental behavior may help explain these findings as they attempt to synthesize the many conflicting factors that influence pro-environmental behaviors (Gifford & Nilsson, 2014; Kollmuss & Agyeman, 2002). These include those that are personal (e.g., childhood experiences, environmental knowledge, values, attitudes, and emotional involvement) and those that are external and social (e.g., sociocultural, economic, and political influences). The differences between donating and nondonating students investigated here regarding their compassion for people and nature impacted by contentious environmental issues, sociocultural awareness, and pro-environmental intent reflect the personal and social factors described by theories of pro-environmental behavior. Furthermore, that the students were given the monetary incentive, and then were provided an opportunity to donate that money reflects an externally imposed economic choice. When making this choice the students were at the conclusion of the Yellowstone trip and some were observed deliberating the extent they might use the money for food and souvenirs, or give it to friends who needed it.

However, pro-environmental behavior frameworks appear to lack meaningful reference to the nature of environmental science and how culture can influence the research and resolution of contentious environmental issues. Criticism has been aimed at frameworks more central to science education (e.g., Science, Technology and Society) for similarly failing to forefront epistemological issues with sociocultural factors, ethics, and other considerations (Hipkins, Barker, & Bolstad, 2005; Zeidler, Sadler, Simmons, & Howes, 2005). Research must focus on how responsible socioscientific decisions appear to manifests from a combination of many important, yet alone insufficient, interrelated factors to include science content and NOS understanding, character and values, group membership, and sociocultural awareness.

5.4 | Limitations

This investigation firmly established an association exists between NOS views, compassion for others, pro-environmental intent, and pro-environmental actions. However, the limitations of this study inhibit generalizability and clarity regarding the nature of the relationships between these and other factors that promote widespread behaviors aimed toward environmental stewardship and societal well-being. Among the limitations of this study are those related to its methodology and the participants sampled.

First, this investigation lacked a control group, which could have experienced classroom SSI instruction reflective of the themes (e.g., NOS, perspective about wolf reintroduction) present in Table 1. Therefore, the differential impact of the SSI instructional intervention versus the place-based context on students' NOS views, compassion, and pro-environmental engagement is underdetermined in this study and remains an open question worthy of investigating. Second, the students investigated here are a small group who self-selected to participate on the trip to Yellowstone. Despite lacking awareness of the SSI instructional intervention prior to self-selection, they may have possessed other characteristics (e.g., high affinity for nature, interest in environmental science) that impacted their performance through that intervention. Third, the students investigated here were enrolled in grades 7–11, with very few enrolled in the latter two grades. This inhibited the ability to conduct meaningful statistical analyses that could determine if the students varied in respect to their NOS views, compassion, and pro-environmental engagement due to grade level related factors (e.g., maturity and school experiences). Future studies could focus on how varying student characteristics such as demographics (e.g., grade, ethnicity, socioeconomic status) and pre-existing motivational features impact students' performance through place-based SSI instructional interventions.

Another limitation relates to how the students' behaviors and the cognitive and emotive factors associated with those behaviors may have varied if they were faced with different pro-environmental choices other than donating 10 dollars to a Yellowstone environmental organization. More simply, would NOS views and compassion for others matter if the stakes were perceived to be much higher (e.g., giving up $100 instead of $10)? Others have argued that self-interest typically outweighs other considerations (e.g., understanding of a science issue, caring for others, and the environment) when pro-environmental behaviors become too personally costly (Herman, 2015; Kollmuss & Agyeman, 2002). Further investigation is needed that demonstrates how cognitive and affective factors such as NOS understanding, compassion for others, and risk aversion relate to the enactment of pro-environmental behaviors that impose varying magnitudes of cost.

Relatedly, perhaps that the donating students developed and exhibited advanced NOS views, compassion for others and pro-environmental intent is indicative of a more encompassing set of personal characteristics that were not accessible through this investigation's approaches. Zeidler et al., 2013 and Zeidler (2016) propose that higher levels of epistemological sophistication enables people to engage in more advanced socioscientific reasoning and account for the protracted implications that stem from socioscientific decisions. Others have demonstrated that environmentally sustainable engagement is positively related to conscientiousness, openness, and the ability to consider and plan for longitudinal consequences (Corral-Verdugo & Pinheiro, 2006; Gifford & Nilsson, 2014; Milfont & Sibley, 2012). Highly sophisticated ways of knowing which enable people to effectively negotiate problematic situations and interpersonal relationships are a function of experience and development, and can be nurtured through a compassionate and progressively complex curriculum that encourages students to balance cognitive, social, affective, and interpersonal construction (Kegan, 1994). Science education efforts must determine and implement practices that holistically prepare students for a lifetime of negotiating the multiple, often conflicting, complexities they will encounter when resolving SSI.

5.5 | Pedagogical implications

This investigation bolsters discussions about how situated learning could be leveraged to better prepare students to understand NOS, become socioculturally aware, and engage SSI across a variety of contexts. When describing situated learning Sadler (2009), explains that knowing and learning are a function of the participants and the contextual environment they experience, in addition to the available ideas, tools, and physical resources. Sadler goes on to compare the distinct differences between a student completing a step-wise science classroom activity focused on amplifying DNA through polymerase-chain-reaction (PCR), and a student participating in a genetics laboratory with a community of researchers that provide scaffolding experiences involving PCR and related genetics topics. While both contexts address PCR, the former is quite impoverished, artificial, and disconnected from authentic science in comparison with the latter where the student participates in a community of practice and acquires knowledge about the conceptual and physical tools involved with genetics research.

This investigation appears to be at the forefront of extant SSI research in regard to the extent students were situated within an authentic real-world context. The place-based SSI instruction occurred over six days within Yellowstone—where the controversial environmental issue of wolf extirpation and reintroduction originated and still persists. The students were provided multiple concrete scaffolding experiences through constructivist approaches that helped them develop an awareness of the diverse perspectives among scientists and local community members, which exemplified the normative and non-normative facets of this issue. For instance, the students experienced wolf watching with ecologists, whose work associated with the Yellowstone wolf reintroduction project includes research on the wolves' ecological impact and outreach to groups who hold polarized views about wolves. When interacting with the wolf ecologists, the students learned about ecosystem dynamics, the nature of ecological research, and how contentious environmental issues such as wolf extirpation and reintroduction entails sociocultural and moral concerns. These experiences were used to introduce readings, reflective questions, and discussions focused on other complex topics—such as the contention within the scientific community about the appropriateness for using top–down trophic cascade theory to account for the impact wolves have on Yellowstone.

Pedagogically, the place-based SSI instruction forcefully promoted students to deeply engage NOS and consider how people and nature are impacted by contentious environmental issues. Perhaps the positive impression the place-based SSI experience had on the students was due to the progressive instructional approaches implemented under real-world conditions where they personally encountered contentious environmental issues firsthand. Gifford and Nilsson (2014) postulate that among adults, the strongest predictor of environmental concern is the amount of nature experiences they had as children. Science instructional efforts, within and outside formal learning environments, should continue to move beyond providing students abstract and often decontextualized experiences that sanitize how the scientific, private, and public spheres actually respond to SSI (Allchin, 2011; Clough, 2006; Sadler, 2009). Rather, students must be immersed in authentic relevant situations and communities of practice that foster their reflective and flexible application of NOS and sociocultural awareness based on the contextual features of the SSI encountered. Without widespread education tailored toward these approaches, achieving functional scientific literacy at societal levels may prove a Sisyphean task.

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SUPPORTING INFORMATION

Additional Supporting Information may be found online in the supporting information tab for this article.

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