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ARTICLE

Promoting Young Learners' NOS Views Through Place-Based SSI Instruction

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Abstract

Promoting a functional scientific literacy entails preparing people to effectively engage and make decisions regarding real-world socioscientfic issues (SSI) through consideration of the relevant products and processes of science, as well as social, cultural, environmental, and ethical factors. Students can develop a functional scientific literacy through place-based pedagogical approaches focused on real-world SSI that augment formal classroom instruction. This quasi-experimental triangulated mixed-methods study investigated how 50 fourth graders in an intervention group, in comparison to their 79 classmates, developed nature of science (NOS) views through experiencing a place-based Missouri River SSI education Program (MRSIP). Salient themes of the month-long MRSIP included Missouri River human impacts, pallid sturgeon decline and recovery, and how scientists investigate and manage those issues. Our findings demonstrate that the MRSIP participants and their non-participating classroom peers expressed NOS views ranging from those that were largely stereotypical (e.g., science must proceed by a set method in a laboratory) to those that transcended stereotypes (e.g., science proceeds by many methods implemented in various field settings). However, after students participated in the MRSIP, they expressed significantly more sophisticated non-stereotypical views about how scientists research and understand Missouri River SSI and the role science plays in resolving those issues. The comparison group of the MRSIP participating students' classmates realized no such gains across the same time period. Pedagogical implications include how place-based SSI teaching can leverage young learners' sense of place and augment their classroom experiences in ways that help them understand NOS and engage local SSI.

1 Introduction and Literature Review

A bounded version of scientific literacy, sometimes referred to as "Vision I," focuses mainly on the products (e.g., ideas, laws, and theories) and process (e.g., practices) of science (Roberts, 2007). This approach elevates standards, curriculum, objectives, and assessments regarding science, technology, engineering, and mathematics (STEM) concepts that are often detached from everyday contexts. Some science educators have

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sought to promote a more functional scientific literacy framework that reflects Roberts' (2007) "Vision II" and initiatives like the STEAM movement (Zeidler, 2016). This framework advocates that science is grounded within authentic sociocultural contexts and people are prepared to respond to socioscientific issues (SSI, e.g., antibiotic resistant bacteria, climate change, reintroduction of species). Resolving SSI requires that people consider pertinent social, cultural, environmental, and ethical factors (Herman, 2018; Hodson, 2009; Zeidler et al., 2013; Zeidler et al., 2005). Furthermore, people must also develop and apply a flexibly operant understanding of relevant science and nature of science (NOS) concepts.

The expansive scholarship addressing NOS broadly and commonly entails topics such as the ontological and epistemological underpinnings of science, what science is and is not, how science and scientists work, and the relationship between science and society (Clough, 2006). However, distinctions occur across academics regarding how they discuss how NOS should be framed, taught, and assessed, which impacts the role NOS plays for SSI engagement. Prominent NOS researchers such as Lederman (2007) and McComas (2004) have advanced tenet-like lists that are well known throughout the science education field and are intended to summarize much deeper NOS understandings. However, some scholars have expressed concern that teachers may primarily implement NOS tenets declaratively as an "add on" to science learning experiences. Others have indicated such tenet approaches may encourage the implementation of context free or context irrelevant NOS instruction and assessments (Hodson, 2009; Olson, 2018). Such concerns have been identified as a "pedagogical issue" by tenet advocates (Lederman & Lederman, 2014, p. 236). Other scholars aware of this pedagogical issue have advocated that NOS instruction should focus on the similarities and differences that occur across scientific work (Clough, 2006, 2007; Erduran et al., 2019; Irzik & Nola, 2011), and/or be situated in and scaffolded from authentic SSI contexts (Allchin et al., 2014; Herman, 2018).

Scholars have advanced initiatives to teach students the ways NOS presents across diverse scientific disciplines, practices, and contexts that align with promoting a functional scientific literacy. For instance, Clough (2006, 2007) proposes having students inquire about NOS through questions and activities that scaffold across increasingly abstract contexts from those unrelated to science to those that address and compare the actual work of scientists. Irzik and Nola's (2011) "family resemblance" and Matthews' (2012) "features of science" approaches strive to frame NOS as a way of thinking about the characteristics that transcend, are isolated to, and define scientific disciplines. Others have advocated that NOS teaching is a vital component of promoting a functional scientific literacy through helping students to effectively respond to SSI that impact them, their communities, and the environment (Allchin, 2011; Allchin et al., 2014; Herman, 2015, 2018; Hodson, 2009). For instance, Allchin's work expounds that NOS learning and assessments should focus on the factors that shape the reliability of scientific claims encountered in everyday contexts and decisions. Some empirical NOS investigations have sought to implement such recommendations. For instance, Herman (2018) and Herman et al., (2019) determined how secondary students engaging real-world SSI through place-based instruction in Yellowstone National Park considered and developed more informed NOS views related to how scientists investigate environmental issues. The investigation reported here contributes to the aforementioned scholarship focused on NOS learning in everyday lived contexts by investigating how a month long after school program, with a field component, focused on local place-based Missouri River SSI helped fourth grade students learn about and contextualize NOS.

1.1 NOS at the Elementary Level

NOS instruction by elementary (K–6th grade) teachers is scant for several reasons (Akerson et al., 2019). First, consensus is lacking regarding which NOS aspects are developmentally appropriate for elementary students. Second, elementary teachers may exclude NOS because they devote little time to science instruction more broadly, hold NOS misconceptions, lack NOS pedagogical skill, and think that their students are unwilling or unable to understand NOS (Akerson & Abd-El-Khalick, 2005; Akerson et al., 2011). Lastly, resources and standards documents (e.g., Next Generation Science Standards (NGSS); NGSS Lead States, 2013) do not provide sufficient and consistent coverage of NOS and its association with science content and practices, and NOS pedagogy (McComas & Nouri, 2016; Olson, 2018). Regarding the latter point and referring to the NGSS specifically, Lederman and Lederman (2014, p. 237) state:

> The most significant problem regarding NOS is that the NGSS considers itself to be pedagogically agnostic. That is, in general (to be fair, there are some general comments regarding NOS in Appendix H), no recommendations are provided as to how one would teach the identified outcomes for students, only outcomes are provided. How a teacher gets students to achieve the outcomes is not specified.

The extant scholarship on elementary students' NOS understanding and learning has typically occurred in formal school settings and used tenet grounded approaches to promote and assess general NOS views that are untethered to relevant SSI. For instance, Akerson and Abd-El-Khalick (2005) investigated fourth grader's understandings of NOS after having been taught by a NOS knowledgeable teacher for a year. Despite the teacher instructing science through inquiry, the teacher did not explicitly teach NOS and the students did not develop acceptable NOS understandings as measured by the VNOS-B by the end of the year. Akerson and Hanuscin (2007) investigated the NOS practices of three elementary teachers and the resulting NOS views of a subset of the students they taught (kindergarten ($N=15$), first grade ($N=8$), and fifth/sixth split grades ($N=10$)). This investigation demonstrated that through dedicated NOS instruction as part of classroom science activities, the teachers' students who were interviewed using the VNOS-D developed more informed NOS views. Not surprisingly, the students in the first, fifth, and sixth grade appeared to improve their understanding of NOS ideas, such as the tentative, creative, and subjective nature of science, more so than the kindergarten students. Walls (2012) used the VNOS-E questionnaire, interviews, and a Draw-A-Scientist test with a photo eliciting activity to examine how 24 third grade African American students conceptualized scientists and their work. This investigation's combinational study design demonstrated that the students held many stereotypical views such as that science primarily proceeds through procedural experimentation and is conducted by men wearing lab coats and glasses. Brunner and Abd-El-Khalick (2020) demonstrated that moderately contextualized NOS instruction through read-alouds of elementary science trade books instigated modest but tangible impacts on fourth and fifth grade students' views of the creative, inferential, and empirical NOS as measured through modified VNOS-D based interviews.

Studies on elementary students' NOS learning outside of formal classrooms are rare (Akerson & Donnelly, 2010; Leblebicioglu et al., 2019; Quigley et al., 2010). Akerson and Donnelly (2010) investigated how 18 K-2 students developed NOS views through a six-week "Saturday Science" program occurring in a classroom-like setting. The instruction entailed decontextualized and moderately contextualized NOS instruction, with the latter coupled with inquiry activities (e.g., fossil and meal worm activities) targeted on school science topics. Limitations to this study included the inability to assess individual students' NOS views before the program. However, after that program, data supported that the students' NOS views (e.g., creative, tentative, empirical NOS) as measured using VNOS-D interviews improved to some degree, but did not become fully informed. Quigley et al. (2010) investigated a similar K–2nd grade Saturday Science program that focused instead on addressing NOS alongside activities and content focused on travel. In this investigation, that determined students' pre- and post-NOS views using VNOS-D interviews, the NOS instruction appeared to positively impact students' views about the tentativeness of science and the role of scientific observations. However, the students demonstrated lingering struggles with the social and cultural aspects of science and the characteristics of observations and inferences. Leblebicioglu et al., (2019) researched how sixth and seventh grade students developed views about the nature of scientific inquiry (NOSI) through participating in two summer camps involving inquiry-based activities accompanied by explicit instruction on NOSI. Through these experiences, the students' views about how questions guide scientific research, the multiple methods of research scientists use, and the differences between data and evidence became more informed. However, the students' ideas about the diverse purposes of research (e.g., social and economic), justification of scientific knowledge (e.g., more than one valid claim can be argued from the same data), and the social aspect of science (e.g., that scientists collaborate and may negotiate to reach consensus) appeared under-developed after the camp experience. The mixed success of these investigations focused on elementary students' NOS conceptions indicates much more work needs to be done to determine if and how different instructional contexts help young learners understand and apply complex NOS ideas across diverse contexts including SSI.

1.2 Place-Based SSI Contexts for NOS Learning

Selecting meaningful instructional contexts for students relevant to the issues they may face is among the major challenges science educators experience (Gilbert et al., 2011). One potential avenue among many pedagogical approaches for creating compelling science learning contexts is using local or "place-based" issues, which can be leveraged to promote students' sense of place, emotive connections to people and nature, and a functional scientific literacy conducive to resolving SSI (Herman, 2018; Herman et al., 2021; Gruenewald & Smith, 2008). Semken et al., (2017, p. 545) outline five typical characteristics of place-based education (PBE):

1. Content focused explicitly on the attributes of a place (e.g., geology, climate, ecology, culture, economics, history).
2. Acknowledging, and when possible, explicitly incorporating, the diverse meanings that place holds for the instructor [teacher], the students, and the community (e.g., locally situated traditional ecological knowledge and/or scientific knowledge about local natural phenomena).
3. Authentic experiences in that place, or in an environment that strongly evokes the place (e.g., experiential learning, fieldwork, service-learning, immersive virtual field environments).
4. Promoting pro-environmental and culturally sustainable practices and life styles in the places that are studied.

5. Enriching the sense of place of students and instructors alike.

The use of PBE to promote SSI engagement has become increasingly more prevalent in science education scholarship. Outcomes of such place-based SSI efforts have include promoting students' sense of place, contemplation of ethical and sociocultural perspectives, socioscientific reasoning, civic engagement, and understanding of scientific claims and NOS (Birmingham & Calabrese Barton, 2014; Kim et al., 2020; Zeidler et al., 2019). However, simply having students experience a place-based SSI will not achieve such notable ends. Several researchers make clear that the framework of effective SSI instruction entails the required elements of: (1) building instruction around a compelling, relevant, and authentic issue; (2) forefronting the issue early in the instruction; (3) providing students a culminating experience; and (4) higher-order practices (e.g., scientific argumentation, reasoning, decision-making) promoted through scaffolding experiences and deliberative pedagogical support that facilitates students' engagement of the issue from multiple perspectives (Herman, 2018; Presley et al., 2013; Sadler, 2009).

For instance, Capkinoglu et al., (2020) provide an example that demonstrates the extent that pedagogical context and support matters regarding students' learning through place-based SSI instruction. In this study, Capkinoglu et al., (2020) investigated how the quality of argumentation of middle school students engaging five local SSI was shaped by three different learning modalities: (1) outdoor fieldtrips to where the SSI were impacting the community; (2) reading newspaper articles about the SSI; and (3) visual and verbal presentations about each SSI. Despite having first-hand experience with the SSI, the students participating in the field trip group had the lowest overall quality of argumentation out of all three groups in the study. Coincidentally, those same students' learning experiences appeared much less pedagogically structured, timely, and supportive than their counterparts working with newspapers and presentations. Capkinoglu et al., (2020, p. 849) concluded this work by emphasizing the importance of supporting place-based SSI interventions with coincidental and careful scaffolding instruction that makes apparent the complex social and scientific dimensions of SSI through stating:

> experiences with SSIs in their authentic locations are not sufficient by themselves for generating quality arguments; drawing conclusions and making logical judgments about the cases/effects/people encountered in those environments is also required.

Few studies investigate how place-based SSI instruction can promote more sophisticated NOS views. For instance, Herman (2018) investigated how sixty seventh through eleventh grade students' NOS views developed through a week of place-based SSI instruction focused on wolf reintroduction in Yellowstone National Park. Throughout the instruction, the students' experiences, such as watching documentaries about wolf reintroduction and field interactions with wolf ecologists, were leveraged to teach abstract concepts such as the NOS and the scientific, political, and cultural dimensions of wolf reintroduction. After the place-based SSI instruction, the students' conceptions of scientific methodology, nature of scientific theories, role of science in solving environmental problems, among other NOS ideas became significantly more informed and contextualized. Herman's (2018) work illustrates how effectively leveraging highly contextualized and authentic SSI experiences with the explicit pedagogical support necessary for a rich instructional context can improve NOS understanding.

PBE approaches that leverage students' sense of place and forefront the social and cultural aspects of SSI can deepen their engagement with and understanding of science

(Allchin, 2011; Hodson, 2009; Zeidler et al., 2019). However, a paucity of extant investigations explores the capacity for SSI interventions that occur in diverse place-based science learning contexts to improve NOS conceptions at the elementary level. Establishing the efficacy of these approaches is especially needed in elementary settings, where science instruction is often neglected due to a number of factors such as teacher preparation, pedagogical content knowledge, professional support deficits, and perceptions that science content lacks relevance for students (Nilsson & Loughran, 2012; Weiss, Banilower, McMahon, & Smith, 2001).

2 Purpose of the Study

This investigation focuses on the extent that a month-long place-based program, developed through a collaborative effort between a large Midwestern university, a Missouri River conservation and education organization, and a medium-sized local school district, helped fourth grade students learn about NOS as it relates to Missouri River SSI. To ensure the anonymity of the study participants, the program will be identified in this manuscript through the pseudonym: Missouri River Socioscientific Issues Program (MRSIP). The program implemented complementary after school classroom and field trip instruction focused on local Missouri River human use, ecosystem, and endangered species (e.g., pallid sturgeon) issues, and how scientists investigate (i.e., the NOS) those issues. Recognizing that effective science education efforts should promote a broader and more compelling Vision II type scientific literacy, the program instruction also focused on the social, ethical, and emotive aspects of Missouri River SSI. The investigation reported here sought to answer the following questions:

1. What types of NOS views do fourth grade students express when asked about local relevant Missouri River SSI?
2. How do students' NOS views change through experiencing place-based Missouri River SSI instruction?

3 Design and Methods

This investigation used a quasi-experimental convergent mixed-methods design to determine how NOS is expressed by fourth grade students when engaging local Missouri River SSI to varying degrees (Cresswell & Plano Clark, 2011). This design entailed surveying MRSIP participating students and their classmates before and after the MRSIP to determine the program's impact beyond the participating students' typical classroom instruction. Presented below are descriptions of the participants, instructional context, data collection, and analyses.

3.1 Participants and Instructional Context

One-hundred and twenty-nine fourth grade students, 64 males and 65 females, enrolled across six classes in three schools in a medium-sized Missouri city were invited and elected to participate in the study after obtaining their parents' informed consent. The 129 students' classroom experiences prior to and during this study, as determined through interviews of their teachers, entailed science lessons several times a week. Those lessons focused on general and place-based science concepts (e.g., invasive bush honeysuckle) and did not entail explicit emphasis on NOS. For the purposes of this study, the 129 students were parsed into one of three groups based on the extent that they self-selected to experience the MRSIP instruction. Seventy-nine of the students (36 males and 43 females) received basic classroom instruction only (i.e., did not participate on the MRSIP) and served as a comparison group. Therefore, the comparison group students' NOS experiences were limited to those that are fairly typical (e.g., absent or implicit) in elementary classrooms (Akerson et al., 2011, 2019). In addition to their normal classroom instruction, fifty of the students experienced MSRIP instruction in their classrooms for an hour to an hour and a half after school once a week for four weeks. Sixteen of these 50 students (10 males and 6 females) participated in only this afterschool component of MRSIP (sessions 1–3 & 5 described below). The remaining 34 of the 50 MRSIP students (19 males and 15 females) also participated on an educational field trip to a local conservation area on the Missouri River (session 4 described below).

3.1.1 MRSIP Intervention

The MRSIP curriculum development and instruction followed the SSI instructional design elements described in Herman (2018) and Presley et al. (2013) in that it centered on Missouri River issues and their scientific and social dimensions and used research-based science education frameworks. The central themes of the MRSIP were the scientific and social dimensions regarding human use (e.g., channelization and damming) and impacts on the Missouri River Ecosystem and pallid sturgeon decline and recovery. Beyond following the SSI instructional design elements, the MRSIP instruction included explicit scaffolds to the scientific and social dimensions of Missouri River issues and salient NOS themes. First, MRSIP lesson objectives followed NGSS performance expectations: *4-ESS2-1. Make observations and/or measurements to provide evidence of the effects of weathering or the rate of erosion by water, ice, wind, or vegetation*; and *4-LS1-1. Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.* The MRSIP curriculum and instruction also explicitly taught students how to use argumentation and the claims, evidence, and reasoning (CER) framework as an appropriate way of how to use sources of information and contemplate multiple perspectives when considering, discussing, and proposing resolutions to Missouri River SSI (McNeill, & Martin, 2011; Simonneaux, 2008; Zembal-Saul et al., 2013). However, unlike many applications of the CER framework, in addition to examining and using scientific claims and evidence, the students also considered non-scientific claims and evidence (e.g., economic, ethical, social) when engaging SSI. The NGSS and CER-based activities served as a scaffolding point to address NOS ideas such as (1) the methodological approaches scientists use to research, collect evidence, and make reliable claims about pallid sturgeon; (2) how and why scientists' claims about pallid sturgeon may differ; and (3) the scientific and non-scientific (e.g., social, historical, economic, and ethical) considerations involved in pallid sturgeon management and recovery. Table 1 below presents the salient instructional themes and activities of each after school lesson and the field trip.

Table 1 Structure of the MRSIP

Session 1 objective: Students learn how scientists investigate the Missouri River and to use Claims, Evidence, and Reasoning (CER) framework.

Activities:

1. Interactive discussion that elicits students' knowledge and experiences about the Missouri River.
2. Students learn about CER framework through activity where students analyze claims and evidence regarding concrete topics (e.g., relation between amount of sleep and paying attention in school). Instructor models and explicitly teaches how to use the CER framework using these topics.
3. Picture walk introducing representations relevant to article about Missouri River SSI of pallid sturgeon recovery. Students make evidence-based claims about the pictures.
4. Facilitated CER analysis of Missouri River SSI article, diagrams, and pictures that presents the scientific, economic and social aspects of two plans for pallid sturgeon recovery (see Appendix A). Student groups share and compare claims and evidence regarding which plan would be more successful in recovering pallid sturgeon populations. Students attend to NOS ideas of how and why claims and evidence used by scientists may be different based on the aspects of each plan.
5. Discussion of how CER is a way to think about and discuss SSI, how science often uses a CER approach, and how scientists' CER may differ but still be valid.

Session 2 objective: Students learn using CER about sturgeon adaptions and habitat and NOS ideas.

Activities:

1. Students use CER framework to examine pallid sturgeon adaptations and their habitat through photos and videos coupled with scaffolding questions. Themes focus on how pallid sturgeon are restricted to certain environments because of their morphology, feeding behaviors, and reproductive needs.
2. Interactive presentation, supported by video of pallid sturgeon, on the concept of adaptations and habitat. Presentation also addresses NOS ideas such as how observing and making explanations through a CER approach about pallid sturgeon adaptations and habitats is a valid way scientists learn about the natural world.
3. Students rotated between four hands on activity stations and used scientific practices (e.g., modeling, asking questions) to further explore pallid sturgeon adaptations and habitat. Students asked in small group discussions at stations about NOS ideas such as how scientific methods do not often follow a step-by-step approach and why scientists' observations, claims, and evidence about the same aspect of nature might differ.
4. Large group discussion about NOS ideas such as how scientists investigate pallid sturgeon, and how those approaches facilitate gathering evidence and making valid claims. Students asked to reflect how they used CER to complete activities.

Session 3 objective: Students learn about the scientific, economic, social, and environmental facets of Missouri River SSI, and how historical changes (e.g., dams and channelization) to the river impacts pallid sturgeon.

Activities:

1. Students learn about natural and human induced species endangerment and extinction through Missouri River Watershed fossil activity and interactive presentations. Activity focuses on the scientific practice of using observations to gather evidence and construct claims.
2. Students rotate through four stations, students explore: (1) the various human alterations to the Missouri River (e.g., modeling dams, channelization, flooding); (2) the social, economic and environmental facets of those alterations; and (3) how those alterations relate to the decline in pallid sturgeon population. Station activities include stream tables, sedimentation simulations, and pictorial real-world examples of engineering on the Missouri River near the students' home community.
3. Interactive presentation on NOS ideas such as how scientists' research on and recommendations about pallid sturgeon are tentative, ongoing, and exhibit some disagreement (e.g., use of chutes vs. interception habitats).
4. Students discuss how new evidence and knowledge impacted their thinking about the claims they made in Lesson 1.

3.2 Survey Development

The MRSIP survey broadly presents sets of items regarding: (a) pallid sturgeon adaptations

Table 1 (continued)

Session 4 field trip objective: Travel to a Missouri River conservation area and experience four field stations. Students learn about pallid sturgeon management and research and associated NOS ideas.
Field stations:
1.Students experience a guided boat tour to observe and learn about river channelization, a river chute, and interception habitat intended to promote pallid sturgeon recovery. Themes addressed include human engineered impacts on the Missouri River and the science underpinning and how scientists are evaluating pallid sturgeon recovery efforts.
2.Students asked scaffolding questions that relate boat tour experience with experiences and knowledge gained from the rest of the MRSIP. Students reflect through white boarding activities on NOS aspects such as scientists' use of creativity and imagination in research, how and where research can occur through multiple methods, how scientists' resolutions can consider the cultural and economic dimensions of SSI.
3.Interactive presentation with fisheries biologists where students practice and learn about real-life scientific practices and methods use to study pallid sturgeon. This includes hands on activities where students simulate conducting sturgeon free embryo and larvae counts.
4.Students revisit salient MRSIP themes through watercolor sketches and notes. They then compare and contrast how observations are used in art and science. Students then discuss historical (e.g., Maria Sibylla Merian) and contemporary figures (Julie Freeman) who's work intersects art and science.
Session 5 objective: Students apply what has been learned in MRSIP to engage in scientific argumentation to propose and select solutions that support pallid sturgeon recovery.
1.Students review experienced MRSIP activities, the two possible solutions (chutes and interception habitats) for pallid sturgeon recovery, and the scientific, economic, and social aspects of each plan.
2.Interactive presentation addressing the norms of scientific argumentation. Themes addressed include how scientists use CER, and how to consider the perspectives of scientists and non-scientists (e.g., farmers, local communities) when considering the two Missouri River SSI solutions.
3.Students work in one of two teams to develop a CER based argument to support one of the two solutions. Students are facilitated to include historical, social, and scientific aspects associated with their solution.
4.Students present their arguments and counterarguments to an independent panel of their peers. The panel then renders a decision based on the validity of the arguments and evidence presented.
5.Students participate in a discussion focused on types of claims, evidence, reasoning and perspective taking (e.g., scientific and non-scientific) in the arguments and solutions. NOS themes focused on include how scientists may disagree and should consider different perspectives when conducting their work and making recommendations. Discussion also focuses on how students' perspectives changed through MRSIP.

and their preferred habitat; (b) historical changes to the Missouri River, and the associated negative impacts on pallid sturgeon; and (c) scientists' investigations and claims regarding pallid sturgeon decline and how to resolve this issue. However, the MRSIP survey items of interest in this investigation focus on the latter topic and assess the NOS views of (1) the methodological context regarding where and how scientists investigate pallid sturgeon; (2) the extent scientists' observations and interpretations (i.e., claims) can disagree; and (3) the extent that science (vs. non-science factors) should be the sole determinant for resolving SSI (e.g., pallid sturgeon decline). These NOS themes were selected because of their perceived developmental appropriateness for young learners based on prior scholarship (Akerson et al., 2011; Leden & Hansson, 2019).

MRISP survey construction occurred over several steps informed by inputs from elementary students and teachers and science education faculty. First, the first and fourth authors, in consultation with the participating school district's science supervisor, established the learning objectives, assessment goals, and structure of the MRSIP. It was determined at this point that the survey content and structure should be highly contextualized using MRSIP focal issues, align with the NGSS performance expectations: 4-ESS2-1 and 4-LS1-1, and explicitly assess NOS themes. These parameters and prior scholarship (see literature review) guided the first author to develop an initial version of the MRSIP survey. The NOS items on the MRSIP survey were constructed through drawing from previously published NOS assessments and modifying those items to be grade appropriate and contextually relevant to the targeted SSI (Cakici & Bayir, 2012; Herman, 2018; Liang, et al., 2008). Use of items customized to the SSI context was justified as it has been argued in science education scholarship that generic decontextualized NOS assessments may inhibit students from expressing nuanced NOS features as they relate to important SSI considerations (Herman, 2015, 2018; Hodson, 2009).

The completed initial MRSIP survey was then reviewed for content validity and readability by the fourth author and a fourth grade elementary teacher with ten years of teaching experience who worked within the participating school district. Based on this review, the MRSIP survey was revised, and then pilot tested with 16 of the fourth grade teacher's students. Pilot testing efforts provided several indicators that the MRSIP survey is comprehensible and reliable for assessing fourth grade students' conceptions regarding Missouri River SSI. First, the teacher ascertained through discussion with her 16 students that the pilot survey is highly comprehensible. Furthermore, the survey asked students to respond to the following questions: *Were there any questions you did not understand or that you were unable to answer completely? If yes, please explain which questions and what you did not understand or what made it hard for you to finish them*. Fourteen of the sixteen students responded no to the first question. Of the two students who responded "yes," one stated being confused, on topics associated with two questions separately: what "sturgeon" and "draw and explain" mean. The other student indicated, without specifying, that one of the survey questions was difficult to understand in comparison to the others.

A review of the piloted surveys also indicated that the survey items prompted the students to provide well-conceptualized and reliable responses to the questions. For instance, Kuder-Richardson formula 20 (KR-20) and mean inter-item correlations (IIC) among forced-choice items measuring students' views of the NOS dimensions, respectively, range from 0.48 to 0.74 and 0.27 to 0.44. Adequate internal consistency values reported in the literature range from 0.50 to 0.70, and those above 0.70 being cited as desirable (DeVellis, 2003; Tan, 2009). However, shorter scale length (< 10 items) can result in lower internal consistency values. In these instances, as is the case with this study (see Table 1), average inter-item correlations should be reported with those exceeding 0.20 indicating satisfactory internal consistency (see Briggs & Cheek, 1986; Clark & Watson, 1995). Furthermore, comparisons between the students' forced-choice, written and illustrative responses indicated those responses triangulated well. Because of the feedback from the teacher, her students, and positive pilot results, only minor revisions (e.g., formatting, providing color pictures) were made to the MRSIP survey prior to data collection (see supplementary materials for the full MRSIP survey—Appendix A).

The final MRSIP survey is highly contextualized (e.g., accompanied with images of pallid sturgeon morphology and anatomical features and historical Missouri River changes) to Missouri River SSI, and, again, asks students to respond to NOS ideas through forced choice prompts, and then prompts students to qualitatively explain their forced choice responses through text and drawings. The use of children's drawings, particularly of scientists' workplaces, alongside textual responses has been used in science education research to reveal distinctive insight into their conceptual understanding of and attitudes about science concepts and practices (Rennie & Jarvis, 1995; Scherz & Oren, 2006). Using mixed methods approaches such as these enables cross-comparison and triangulation across the students' forced-choice and qualitative responses and enhances reliable assessment of their NOS views (Herman, 2018; Cohen et al., 2011).

3.3 Data Collection

The 129 students investigated here completed the MRSIP survey within one week before and one week after the MRSIP program was implemented. Survey administration was conducted with the aid of the students' teachers during class time, who assisted students needing help with reading and comprehending the survey items. Students were instructed to complete all items thoroughly, to the best of their ability, and write "I don't know" if they did not know the answer to qualitative items. While all 129 students' data are included in this study, not all students were able to complete all portions of the survey in the time (≈30–40 min) that teachers allocated. Therefore, response rates ranged from 98% for earlier survey items to 61% on the later survey items (sample size for each NOS dimension are reported in the Findings section). However, the response rates appear sufficient in consideration of literature that states typical survey efforts should achieve a minimum response rate of 50–60% in order to obtain representative samples (Fincham, 2008).

3.4 Data Coding, Efficacy, and Analyses

A multi-step process was used to validate, code, analyze, triangulate, and integrate students' forced choice and qualitative NOS responses (Cresswell & Plano-Clark, 2011). This approach facilitated a robust account of how the place-based MRSIP instruction influenced the students' NOS views. As indicated before, the MRSIP survey presents content and questions about pallid sturgeon and Missouri River habitat changes, 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 NOS items analyzed here.

The coding of qualitative data sources was conducted by the first three authors and occurred through a multi-step semi-inductive approach (Lincoln & Guba, 1985; Miles & Huberman, 1994; Patton, 2002). First, rubrics and taxonomic themes were conceptualized and developed that ascertain the extent that students demonstrated nonsensical and stereotypical (i.e., naïve) to explicitly transcending (i.e., clearly articulated and accurate) views in regard to each of this project's three focal NOS dimensions of: (1) the methodological context regarding how and where scientists' investigate pallid sturgeon; (2) the extent scientists' observations and interpretations can disagree; and (3) the extent science (vs. other factors) should be the sole determinant for resolving environmental science issues. The rubric's taxonomic themes for each NOS dimension were developed by drawing from NOS frameworks and coding schemes established through prior scholarship. For instance, we considered that frameworks that advocate the consideration of NOS aspects must be flexibly operant based on the science context and that the NOS can be implicitly and explicitly conveyed (Clough, 2006, 2007; Herman, 2015). We also considered NOS coding schemes from scholarship such as Cakici and Bayir (2012) and Kruse and Wilcox (2011). The former coded 10 and 11-year-old students' naïve (i.e., stereotypical) to informed responses across five NOS aspects including the multiple methods of investigations and sociocultural embeddedness of science. The latter gauged how students' written response and drawings reflect stereotypical connotations of scientists, their workplaces (e.g., lab vs. non-lab settings), and methodological approaches.

Rubric construction, coding, and scoring occurred for each NOS dimension separately. First, the first three authors collaborated to develop provisional taxonomic schemes for the focal NOS dimension. The taxonomic scheme for that NOS dimension was then independently evaluated by repeatedly reading and comparing 25 to 30 students' responses to the taxonomic scheme's descriptions. Next, the authors met to critique and refine the taxonomic scheme for that NOS dimension and its descriptors. This process was repeated with a new group of 25 students' responses until the authors fully agreed that, for that NOS dimension, the taxonomic scheme could be considered a systematic coding rubric with categories and descriptors that were saturated, represented the full range of the students' expressed views, and were sufficiently characterized through exemplars.

The authors then piloted the coding rubric for each NOS dimension through independently matching 10 students' responses to the most corresponding coding category. This was followed by the authors comparing matches and adjusting coding descriptors. This process was repeated until the authors matching of students' responses to corresponding coding categories for each NOS dimension reached 80%. The final rubrics for each of the three NOS dimensions displayed a range of five scores that gauge the accuracy and explicitness of the students' NOS views: uninformed (i.e., naïve and irrelevant to NOS dimension, score = 0), stereotypical (i.e., naïve but relevant to NOS dimension, score = 1), transitional (i.e., mix of stereotypical and transcending NOS views, score = 2), implicitly transcending (i.e., informed but with implicit/tacit elements, score = 3), and explicitly transcending (i.e., informed and explicitly stated, score = 4) NOS views (see Table 2 below). Exemplars for each coding level appear in the findings.

The rubrics were then used to score the students' qualitative NOS responses regarding each NOS dimension separately through a multi-step process. First, the authors used the independently scored 25 to 30 of the students' qualitative responses, which was then followed by meeting and recalibrating coding approaches through cross comparing instances of agreement and disagreement. This process was repeated with each group of students' responses until at least an 80% inter-rater agreement across the three coding authors was achieved. After which, the authors met to resolve any scoring discrepancies, which was aided through reflective triangulation of data sources. For instance, following advice provided by Bland (2012, 2018) and Rennie and Jarvis (1995), the interpretation and coding of students' drawings were corroborated through comparison with the students' textual and forced choice responses. Through the focusing on NOS dimensions individually, independent review of data sub-sets, inter-rater checks, and data triangulation, the researchers sought to ensure the findings, interpretations, and presentation of the qualitative taxonomies of the students' NOS views assume high degrees of trustworthiness, validity, and substantive significance (Patton, 2002).

The students' forced choice NOS responses were scored as 1 = selecting a correct NOS view or not selecting an incorrect NOS view, or 0 = selecting an incorrect NOS view or not selecting a correct NOS view. Then, a total score was calculated for each student's responses to each set of forced choice prompts for each NOS construct. KR-20 and mean inter-item correlations, respectively, ranged from 0.56 to 0.72 and 0.23 to 0.56., thus indicating satisfactory internal consistency (see Table 3). Significance testing (e.g., Wilcoxon rank sum) was conducted on the scores derived from students' forced choice and qualitative responses to compare how the NOS views changed among student groups who experienced

Table 2 Rubrics for the three NOS dimensions

	NOS dimension		
	Methodological context: how and where scientists' investigations occur	Appropriateness of disagreement among scientists' simultaneous observations and claims	Role of science and non-science factors for SSI resolution
0 Nonsensical/ uninformed	Nonsensical and/or irrelevant representation or writing "I don't know"	Nonsensical and/or irrelevant representation or writing "I don't know"	Nonsensical and/or irrelevant representation or writing "I don't know"
1 Stereotypical	Bounded by explicitly stated stereotypical views such as that scientists only work in a lab and/or use only stepwise experimental methods	Explicitly indicates that scientists' simultaneous observations and/or claims (i.e., thoughts & interpretations) must agree	Resembles scientism—explicitly indicates that science and scientific evidence is the only source of contentious environmental issue resolution
2 Transitional	Mix of explicitly stated stereotypical and non-stereotypical views such as situating scientific research on the river, but indicating experiments and/or step-by-step methods are required. OR exclusively indicates non-stereotypical research place OR methods such as indicates multiple methods, but no place of research	Tentative whether disagreement may happen (e.g., vacillates between disagreement and agreement) with no justification, or simply that disagreement may occur because of different observations or that it prevents both people from being wrong	Tacit and generic indication that other factors beyond science might be considered for SSI resolution (e.g., generically indicating science is not always correct or that other people or the public can have ideas or feelings)
3 Implicitly transcending	Mix of implicit (e.g., student implies observations of a pallid sturgeon are occurring through drawing) and explicit (e.g., scientist are clearly researching on river) non-stereotypical views about place and methods	Explicitly indicates disagreement is normal (no representation of process) with implicit/tacit justification (e.g., that disagreement derives from and/or is a function of thought generation or learning processes)	Explicitly recognizes other factors and/or stakeholders beyond science/technology for SSI resolution. However, factors and stakeholders are implicitly and/or tacitly described (e.g., local groups may have knowledge about sturgeon, needs, or people must participate in SSI resolution such as removing dams and trash or voting)

Table 2 (continued)

	NOS dimension		
	Methodological context: how and where scientists' investigations occur	Appropriateness of disagreement among scientists' simultaneous observations and claims	Role of science and non-science factors for SSI resolution
4 Explicitly transcending	Views about place and methods expressed explicitly and transcend stereotypical views in that the students convey many methods beyond step by step controlled experiments are appropriate and that scientists work occurs beyond lab settings (e.g., scientists using tags and trackers to collect observational data from a riverbank or boat; appropriate indication research can occur in both the lab and habitat)	Explicitly states disagreement is a normal process of ongoing scientific inquiry with explicit/overt justification (e.g., disagreement is a process that moves scientific thinking forward and/or toward the truth)	Explicitly states and specifies factors and/or stakeholders beyond science/technology for SSI resolution. Factors are typically distal and abstract (e.g., cultural, economic, historical, geographic, property rights, multidisciplinary and beyond science)

the full MRSIP program (including the field trip) and classroom instruction, only the after school portion of MRSIP and classroom instruction, and only classroom instruction. Baseline significance tests (e.g., Kruskal–Wallis H and Mann–Whitney *U* tests) were also conducted to determine if significant differences existed across the pre-MRSIP scores of the three student groups. Effect size interpretation for nonparametric statistical tests followed Cohen (1988) (r: 0.1 = small, 0.3 = moderate, and 0.5 = large effect).

4 Findings

Prior to the MRSIP, the three student groups experiencing (1) the full MRSIP program and classroom instruction, (2) only the after school portion of MRSIP and classroom instruction, and (3) only classroom instruction demonstrated largely similar NOS views, with the exception of how they qualitatively considered how scientists conduct research on pallid sturgeon. However, students experiencing the MRSIP program demonstrated significant gains in their NOS views to some degree across all three dimensions, whereas their non-participating classroom peers did not. The findings presented below are organized in sections according to the three NOS dimensions addressed in this investigation. Within each section, we present the extent that each of the three groups' NOS views as measured through forced choice responses changed from before to after the MRSIP. We then describe the extent each of the three groups' qualitative NOS views changed from before to after the MRSIP.

4.1 Methodological Context: How and Where Scientists' Investigations Occur

Kruskal–Wallis *H* tests demonstrated no significant differences existed across the MRSIP participating students and their non-participating peers pre-MRSIP forced choice elicited views regarding the methods (e.g., controlled stepwise experiments vs. many methods) and location (e.g., exclusively in a laboratory vs. in sturgeon habitat) of scientists' investigations ($p > 0.05$, Table 4). A Kruskal–Wallis *H* test demonstrated significant differences among the students' pre-MRSIP scores measuring their qualitative views about the methods and place scientists investigate pallid sturgeon ($p = 0.016$, $\chi^2 = (2, 121)\ 8.3$). Follow-up Mann–Whitney *U* tests showed that students electing to complete all aspects of the MRSIP demonstrated significantly and modestly higher pre-scores than their MRSIP non-participating classroom peers ($p = 0.005$. $Z = -2.8$ $r = 0.27$). No other significant differences were detected across the three groups' pre-MRSIP scores measuring their qualitative views about how and where scientists investigate pallid sturgeon.

Wilcoxon rank sum tests demonstrated that the forced choice response scores of students experiencing the full MRSIP program and their peers experiencing only classroom instruction did not appreciably change from before to after the MRSIP implementation (Table 4). The students who experienced only the after school portion of MRSIP in addition to their normal classroom instruction did not demonstrate a significant change in their forced choice response scores measuring whether scientist investigate pallid sturgeon in the laboratory or in their natural habitat. However, this group's forced choice response scores measuring the extent that they thought many methods must be created and used to investigate pallid sturgeon demonstrated significant and moderately large gains after completing the MRSIP ($p = 0.015$, $Z = -2.43$, $r = 0.43$). None of the MRSIP participating and non-participating student groups' qualitative scores regarding this NOS dimension demonstrated appreciable changes from before to after the MRSIP occurred ($p > 0.05$).

Table 3 Description of NOS prompts and items

NOS dimension	# of items	Contextual prompt	Example item	Pilot KR-20/IIC	Pre KR-20/IIC	Post KR-20/IIC
Methodological context: *how* investigations occur	2	Mr. Oliver and Ms. Jenna are scientists that study fish. Please answer how you think Mr. Oliver and Ms. Jenna should investigate pallid sturgeon if they want to get good evidence and make truthful claims about them.	A step-by-step experiment is not always the best. They (scientists) must create and use many different methods for their investigations.	.48/.38	.56/.39	.72/.56
Methodological context: *where* investigations occur	2		They should only investigate pallid sturgeon in the laboratory.	.55/.44	.56/.40	.62/.45
Disagreement among scientists' simultaneous observations and claims	4	At the same time, the scientists Mr. Oliver and Ms. Jenna observe and make claims about how and why a pallid sturgeon uses its barbels.	Their (scientists) thoughts about the same things they observed should always be the same and agree.	.74/.43	.62/.30	.74/.41
Role of science and non-science factors for SSI resolution	5	Mr. Oliver and Ms. Jenna are scientists who were talking about how environmental problems like sturgeon populations declining should be fixed.	Other things besides scientific evidence (like public opinion) should be used when fixing environmental problems like this.	.66/.27	.59/.23	.71/.34

Table 4 Pre- and post-median scores measuring students' views about the methodological context of how and where scientists' investigations occur

Student group	N	How investigations occur (forced choice)		Where investigations occur (forced choice)		How/where investigations occur (qualitative)	
		Pre MD	Post MD	Pre MD	Post MD	Pre MD	Post MD
No MRSIP	77	2.0	2.0	2.0	2.0	2.0 ‡	2.0
MRSIP no field trip	16	1.5 †	2.0 †	2.0	2.0	2.0	2.0
MRSIP with field trip	33	2.0	2.0	2.0	2.0	3.0 ‡	3.0

†Significant pre to post difference within groups

‡Significant pre difference across groups

The MRSIP non-participating students provided the highest percentage of uninformed pre- and post-MRSIP responses about scientist' pallid sturgeon investigations, respectively followed by their classmates who completed only the afterschool, and their classmates who completed all aspects, of the MRSIP (Fig. 1). However, from before to after the MRSIP, 6% to 7% fewer students expressed these views across all three student groups. Characteristic of students' uninformed views about how scientists should investigate pallid sturgeon, Brianna and Chantelle both responded to this topic "I don't know" prior to their beginning and completing all aspects of the MRSIP. Mindy, also a MRSIP full participant, responded similarly before the MRSIP by drawing a question mark. Among those who did not participate in the MRSIP, Adrianna provided a pre, and Glenda provided a pre- and post-MRSIP response also indicating that they did not know or were unsure of how scientists should investigate pallid sturgeon.

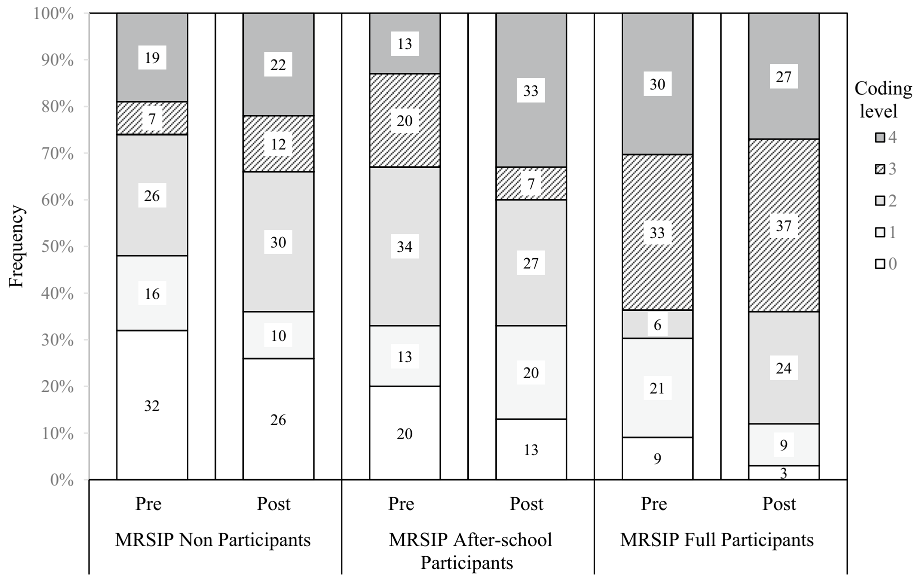


Fig. 1 Distributions of MRSIP non-, after-school, and fully participating students' pre-and post-MRSIP responses about how and where scientists should investigate pallid sturgeon (Note, percentages rounded to whole number and 0 = nonsensical/ uninformed, 1 = stereotypical, 2 = transitional, 3 = implicitly transcending, 4 = explicitly transcending)

Prior to MRSIP, between 13 and 21% of the students not participating and participating in the MRSIP demonstrated stereotypical views about how scientists should investigate pallid sturgeon. Respectively, 6% and 12% fewer of the MRSIP non-participating and fully participating students provided such views on post-MRSIP measures. Conversely, 7% more of the MRSIP after school students demonstrated stereotypical views on post-MRSIP measures about scientists' investigations of pallid sturgeon. More specifically, rather than accurately indicate that scientists use multiple methods or well-established data collection protocols to investigate pallid sturgeon in their natural habitat, these students responded that pallid sturgeon research should occur through stepwise controlled experiments and/or exclusively in laboratory environments. For instance, Jayson and Tom, before starting and completing the full MRSIP program, wrote:

> After [the lab experiment] release them. They don't want to kill the fish and a bear might attack them (i.e., the scientists) in the wild. *Jayson, MRSIP full participant, pre-score "1"*
>
> They should do many experiments and do them in the laboratory. *Tom, MRSIP full participant, pre-score "1"*

Maddie, who completed only the after school components of the MRSIP, provided the following pre-MRSIP drawing on the left in Fig. 2. In this drawing, Maddie indicates pallid sturgeon should be investigated in an aquarium through controlling variables.

The proportion of MRSIP non-participating students demonstrating transitional views about how scientists should investigate pallid sturgeon increased 4% from before to after the MRSIP. The proportion of MRSIP after-school participating students demonstrating similar views decreased 7% across the same time period. However, 18% more of the MRSIP full participants expressed transitional views about pallid sturgeon investigations after completing that program. For instance, Mindy, who's previously described response demonstrated she was unsure of this NOS dimension before the MRISP, drew the illustration below after the MRSIP (Fig. 3).

Coded as "transitional," Mindy's response partially addresses NOS conceptions taught through the MRISP instruction she experienced. More specifically, Mindy advocates that the most appropriate place to study pallid sturgeon is in their natural habitat. However, she provides no indication of the kinds of methods scientists should use when doing so, despite this NOS theme being explicitly addressed during the MRSIP. Jayson, who provided a stereotypical pre-MRSIP response that was previously addressed, expressed non-stereotypical

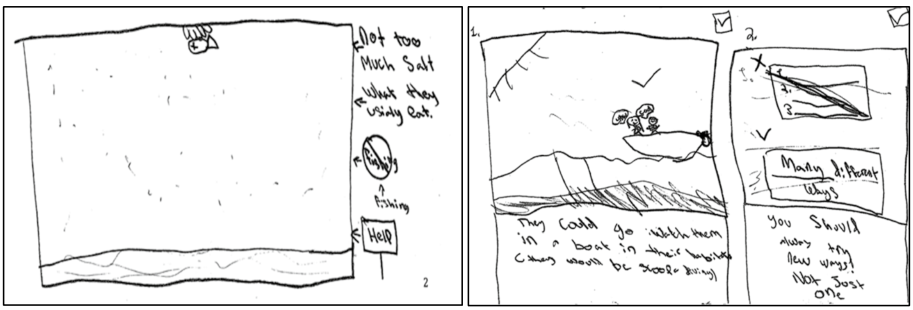
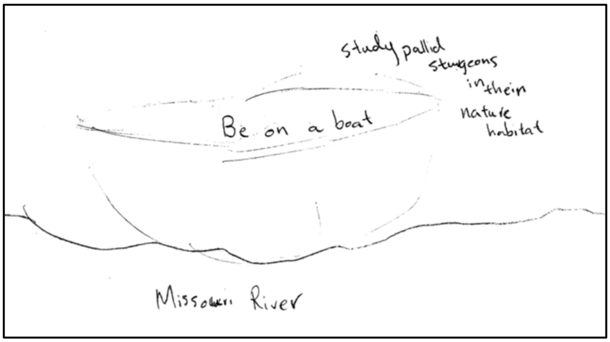


Fig. 2 Illustrations provided by Maddie, *MRSIP after-school participant, pre score "1" (left) and post score "4"(right)*

Fig. 3 Illustration provided by Mindy, *MRSIP full participant, post score "2"*



post-MRSIP views through recognizing that the most appropriate place to investigate pallid sturgeon is in its natural habitat. However, Jayson held onto to some stereotypical views of how those investigations should proceed by emphasizing that scientists need to be very careful to use step by step methods.

> If they do it [investigate pallid sturgeon] in the lab, it won't know where it is and will maybe freak out, and be very careful [by] using step by step. *Jayson, MRSIP Full Participant, post-score "2"*

Similarly, Hannah, prior to beginning the full MRSIP, indicated aspects of pallid sturgeon research should occur under natural conditions. However, she also framed these investigations as step-wise experiments.

> 1) Use a thermometer to see how cold the water is. 2) Catch the fish. 3) Put the fish in different water [to] see how it reacts. 4) Put the fish back in its water. 5) Conduct experiments. Hannah, *MRSIP full participant*, *pre-score "2"*

The percentage of MRSIP non- and full participating students demonstrating implicitly transcending views about how scientists investigate pallid sturgeon marginally increased from before to after the MRSIP, with the former and latter, respectively, changing from 7 to 12% and 33 to 37%. The proportion of MRSIP after school students demonstrating such views reduced from 20 to 7% over the same time period. Providing a pre-MRSIP response

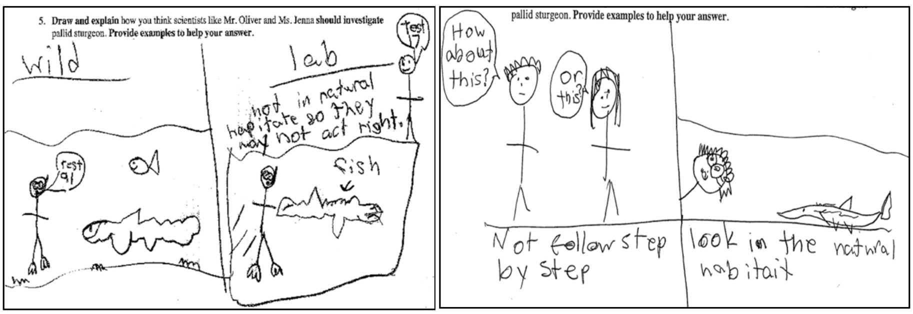


Fig. 4 Illustrations provided by Alex, *MRSIP full participant, pre score "3" (left) and post score "4" (right)*

coded as "implicitly transcending," Alex, one of the MRSIP full participants, drew the illustration on the left below in Fig. 4.

In his pre-MRSIP drawing, Alex makes it clear that if the investigation occurs in controlled laboratory conditions, the fish "may not act right." However, Alex also implies that the appropriate methods for investigating pallid sturgeon should occur through repeated observational "tests." Adriana, a MRSIP non-participant, who's previously addressed pre-MRSIP response was rated unaware, clearly indicates through her post-MRSIP response provided below in Fig. 5 that pallid sturgeon research should occur in their natural habitat. However, she implies that research on pallid sturgeon should proceed through observing how they are affected by varying environments. Brianna's drawing in Fig. 5 below indicates she experienced a similar conceptual shift from being unaware of how pallid sturgeon should be investigated, to indicating after completing the full MRSIP that they should be investigated through observing them in their natural habitat.

The proportion of MRSIP non-participating and after-school participating students demonstrating explicitly transcending views about how scientists should investigate pallid sturgeon, respectively, increased from 19 and 13% before to 22% and 33% after the MRSIP. The proportion of MRSIP students completing the full MRSIP demonstrating such views decreased slightly from 30 to 27% across the same time period. Maddie, who provided a stereotypical pre-MRSIP response addressed in Fig. 2, responded with explicitly transcending views after completing the after school component of the MRSIP. More specifically, Maddie's post-MRISP response in Fig. 2 (1) establishes that the most appropriate place to investigate pallid sturgeon is in its natural habitat and (2) confirms that step by step methods are inappropriate for carrying out such investigations. Alex demonstrated similar views after completing the entire MRSIP program, which were a slight improvement in comparison to his previously addressed pre-MRSIP response (Fig. 4). Tom, who's stereotypical pre-MRSIP views of scientists' pallid sturgeon investigations were previously described, provided the drawing in Fig. 6 after completing all aspects of the MRSIP.

In Tom's illustration, he makes clear that the appropriate way to research pallid sturgeon is by tagging and tracking them in their natural habitat, which is a methodology that was explicitly addressed during the MRSIP. Margaret also provided pre- and post-MRSIP responses coded as explicitly transcending. Her pre-MRSIP response appearing below details that pallid sturgeon must be investigated in their natural habitat through various methodological approaches.

> I think it should be investigated in its habitat, because if not that might cause it to act differently than normal. If they keep using the same strategy, they might not find out

Fig. 5 Illustrations provided by Adriana (left), *MRSIP non participant, and* Brianna (right) *MRSIP full participant, both post score "3"*

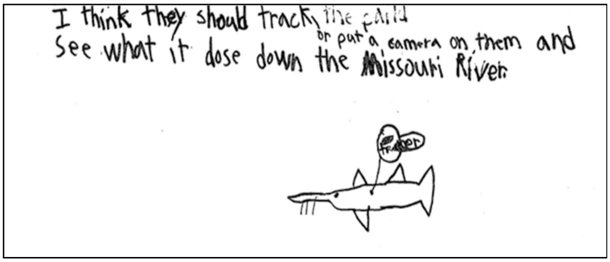


Fig. 6 Illustration provided by Tom, *MRSIP full participant, post score "4"*

more than they already did…and someone else might have already discovered it so their work would be of no use. *Margaret, MRSIP full participant, pre-score "4"*

However, her response after completing all aspects of the MRSIP conveyed similar, yet highly contextualized, depictions of this NOS topic reflective of examples provided during the MRSIP. More specifically, her drawing presented in Fig. 7 advocates that research on pallid sturgeon should involve tracking methodologies.

4.2 Disagreement Among Scientists' Simultaneous Observations and Claims

A Kruskal–Wallis *H* test demonstrated no significant differences across the MRSIP participating students' and their non-participating peers' pre-MRSIP forced choice responses regarding the extent scientists' observations and thoughts (i.e., claims) occurring at the same time can disagree ($p > 0.05$). A Kruskal–Wallis *H* test demonstrated no significant differences across the three student groups' pre-MRSIP scores measuring their qualitative views about the extent that scientists can disagree when making simultaneous observations and claims ($p = 0.07$, $\chi^2 = (2, 113)\ 5.2$). However, because this test approached significance, follow-up Mann–Whitney *U* tests were conducted and showed that students electing to complete the after-school component of the MRSIP demonstrated slightly higher pre-scores regarding this NOS dimension than their MRSIP non-participating classroom peers ($p = 0.04$. $Z = -2.0$, $r = 0.22$). No other significant differences were detected across the three groups' pre-MRSIP qualitative scores regarding the extent scientists' observations and thoughts can disagree (Table 5).

Wilcoxon rank sum tests demonstrated that the students experiencing the after-school MRSIP program and their peers experiencing only classroom instruction did not appreciably change their forced-choice response scores regarding this NOS dimension from before

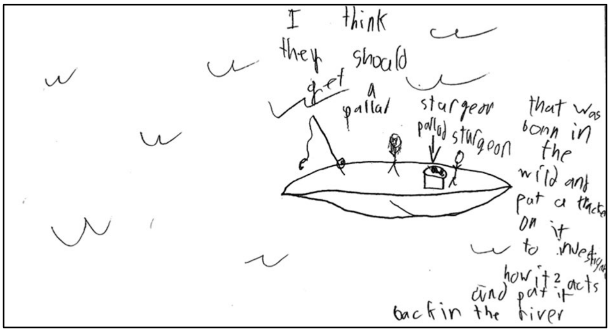


Fig. 7 Illustration provided by Margaret, *MRSIP full participant, post score "4"*

Table 5 Pre- and post-median scores measuring students' views about the appropriateness of disagreement among scientists' observations and claims

Student group		Forced choice		Qualitative	
		Pre MD	Post MD	Pre MD	Post MD
No MRSIP	N	73		71	
		4.0	4.0	2.0 §	2.0
MRSIP no field trip	N	14		13	
		4.0	4.0	3.0 §	3.0
MRSIP with field trip	N	32		29	
		4.0 †	4.0 †	2.0 ‡	3.0‡

†,‡Significant pre to post difference within groups

§Significant pre difference across groups

to after MRSIP implementation ($p > 0.05$). The students who experienced all aspects of the MRSIP in addition to their normal classroom instruction demonstrated significant and moderately large gains in their scores measuring their forced choice responses of whether scientists' simultaneous observations and thoughts can disagree ($p = 0.008$, $Z = -2.7$, $r = 0.36$).

The MRSIP non-participating and MRSIP after-school participating students' pre- to post-MRSIP qualitative responses regarding the extent that that scientists can disagree when making simultaneous observations and claims remained largely unchanged ($p > 0.05$). However, students completing all aspects of the MRSIP demonstrated significant and moderately large gains in their scores measuring their qualitative views of whether scientists' simultaneous observations and claims can disagree ($p = 0.005$, $Z = -2.8$, $r = 0.37$).

The proportion of MRSIP non-participating students providing uninformed views about the extent that scientists can disagree when making simultaneous observations and claims decreased 5% from before to after the MRSIP (Fig. 8). The proportion of MRSIP full participants demonstrating similar views about this NOS dimension also decreased, yet to a larger extent, from 17 to 0% across the same time period. However, the proportion of MRSIP after-school participants that indicated they were uninformed of the extent scientists' thoughts and observations can disagree doubled from 15 to 31% after the MRSIP. Characteristic of students' uninformed views about this NOS dimension, Martha and Amanda, both MRSIP non-participants responded "I don't know" prior to the MRSIP starting. Erica, an MRSIP after-school participant, and Tom, Edith, and Natalie, full MRSIP participants similarly responded prior to beginning that program "I don't know" and "I'm not sure!".

MRSIP non-participants providing stereotypical views that scientists' observations and/or interpretations must always agree reduced from 14% before to 9% after the MRSIP. Before and after the MRSIP, none of the MRSIP after-school and 3% of the full MRSIP participants provided stereotypical views about this NOS dimension. Providing stereotypical views on pre-MRSIP measures, Emily, a MRSIP non-participant, exclaimed the following about scientists' simultaneous observations and claims:

> They need to agree or else they won't come up with the same answers they need. *Emily, MRSIP non participant, pre-score "1"*

Emily's response below, collected approximately a month later and after the MRSIP, indicates she retained these stereotypical views.

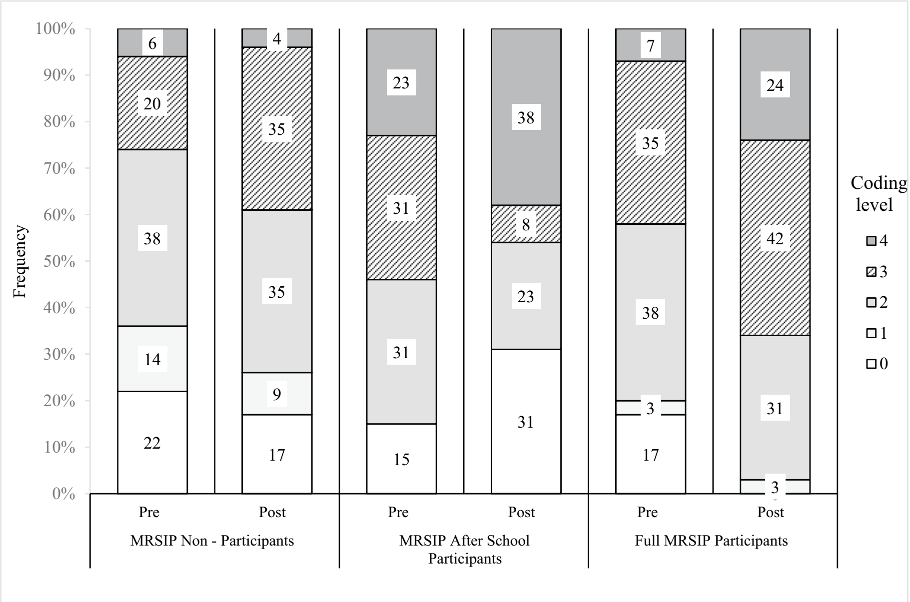


Fig. 8 Distributions of MRSIP non, after-school, and fully participating students' pre-and post-MRSIP responses about the appropriateness of disagreement among scientists' simultaneous observations and claims. Note, percentages rounded to whole number and 0 = nonsensical/ uninformed, 1 = stereotypical, 2 = transitional, 3 = implicitly transcending, 4 = explicitly transcending

> Mr. Oliver and Ms. Jenna (the scientists) shouldn't disagree because they need to have the same facts about the pallid sturgeon so they can experiment without any mistakes. *Emily, MRSIP non participant, post-score "1"*

In both responses, Emily appears to perceive that disagreement among scientists when they observe and make claims about the same thing inhibits creating and possessing useful knowledge. In the case of Emily's second response, agreement among scientists' observations and claims is crucial for ensuring error-free experiments.

The proportion of MRSIP non-participating students providing transitional views regarding the extent that scientists can disagree when making simultaneous observations and claims reduced from 38% before to 35% after the MRSIP. Across the same time frame, the proportion of MRSIP after-school and full participants providing such views, respectively, decreased from 31 to 23% and from 38 to 31%. Ahren's, a MRSIP non participant, pre-MRSIP response below represents a transitional view in that she perceives disagreement results simply from making different observations.

> Because they might make different observations. *Ahren, MRSIP non participant, pre-score "2"*

Stella's, a MRSIP after-school participant, pre-MRSIP response regarding whether disagreement may occur among scientists was rated as implicitly transcending. However, after completing the MRSIP, her response resembled Ahren's above.

They should disagree because they make different observations. *Stella, MRSIP after school, post-score "2"*

As previously indicated, Erica, a MRSIP after school participant, and Edith, a MRSIP full participant, stated they didn't know before completing the entire MRSIP program whether scientists could disagree when making simultaneous observations and claims. After that program, Erica provided the following response that first states agreement is unneeded among scientists. However, she then appears to indicate that scientists must eventually agree about aspects of their evidence.

It really doesn't matter if they agree. Great if they don't, they have to work that out and agree on how much evidence they have. *Erica, MRSIP after school, post-score "2"*

Edith, after experiencing the full MRSIP, provided the response below that represents a transitional view regarding this NOS aspect in that she perceives disagreement results simply from seeing and observing different parts of things.

They can disagree because if someone saw something different in the same part they can have different observations. Edith, *MRSIP full participant, post-score "2"*

Abdullah, also a MRSIP full participant, provided a similar pre-MRISP response.

They should disagree because the sturgeon could do different things letting them have different observations. Abdullah, *MRSIP full participant, pre-score "2"*

The proportion of MRSIP non- and full participating students providing implicitly transcending views that disagreement is normal when scientists make simultaneous observations and claims, respectively, increased from 20 to 35% and from 35 to 42% from before to after the MRSIP. The proportion of MRSIP after-school participants' expressing these views decreased from 31 to 8% across the same time period. For instance, Stella, as previously indicated, provided a pre-MRSIP response coded as implicitly transcending, but provided a transitional post-MRSIP response. Stella's pre-MRSIP response indicates that disagreement can occur among scientists due to different thought processes.

They shouldn't agree *all* the time because they might have different thoughts. *Stella, MRSIP after school, pre-score "3"*

Similarly, Maddie's, also an after-school MRSIP participant, response provided below exemplifies those coded as implicitly transcending.

They should not have to think the same things because everybody is different. Also, they can have different opinions. Maddie *MRSIP full participant, pre-score "3"*

In her response collected before the MRISP, Maddie indicates scientists should be able to disagree when observing and making claims about the same thing, and, tacitly, that disagreement results from varying thought processes and perspectives. Again, Natalie responded prior to beginning and completing the entire MRSIP that she was not sure whether scientists could disagree when simultaneously making observations and claims. Her post-MRSIP response below demonstrates that she recognizes that scientists can simultaneously make different observations of the same things. Furthermore, her response also indicates that the scientists could then contrast those observations.

> They can make different observations and they can take those observations and compare them! Natalie, *MRSIP full participant, post-score "3"*

Abdullah, who provided a transitional pre-MRSIP response regarding this NOS dimension, which is discussed above, indicated after completing the entire MRSIP program through the response below that scientists' observations and claims should disagree as that may facilitate knowledge generation.

> They should sometimes disagree because they could learn new things. Abdullah, *MRSIP full participant, post-score "3"*

MRSIP non-participating students providing views with explicit justification that disagreement among scientists' simultaneous observations and claims is a normal process of ongoing scientific inquiry (i.e., explicitly transcending) decreased slightly, from 6% before to 4% after the MRSIP. Conversely, across the same time frame, the proportion of MRSIP after-school and full participants providing such NOS views, respectively, increased from 23 to 38% and from 7 to 24%. Ahren, a MRSIP non-participant who's previously discussed pre-MRSIP response was rated transitional, provided the post-MRSIP response below that indicates scientists' disagreement when making simultaneous observations and claims enables their ability to make further claims.

> Sometimes they should disagree because that helps make claims [that] they couldn't have if they always agree. Ahren, *MRSIP non participant, post-score "4"*

Maddie, a MRSIP full participant who was previously discussed as providing an implicitly transcending pre-MRSIP response, provided a more explicit response regarding how scientists' disagreements when observing and making claims about the same things actually improve their observations.

> They [the scientists] are different people so they think different things. Different ideas and disagreements make their observations even better. When you work out your disagreements it makes it easier to do it [make observations] again. *Maddie MRSIP full participant, post-score "4"*

Mark's, a MRSIP full participant, pre- and post-responses below both appear to indicate that scientists' disagreements when observing and making claims about the same things lead to more information and advanced knowledge. However, Mark's post-MRSIP response further substantiates his point through contextualized examples drawn from the MRSIP. More specifically, Mark states in his post-MRSIP response that disagreement among scientists helped them more deeply understand how chutes (i.e., an engineered throughway channel in a river bank) and wing dikes (i.e., an engineered river channel training structure) can help recover pallid sturgeon populations.

> If they do disagree then they can learn from each other. If they always agree then they might not get lots of information. Mark *MRSIP full participant, pre-score "4"*
> They shouldn't have to agree because they can find out new things. It can also make them think deeper to realize new things. For example, they couldn't have found out [wing] dikes and chutes could help pallid sturgeon. Mark *MRSIP full participant, post-score "4"*

Table 6 Pre- and post-median scores measuring students' views about the role of science and non-science factors for SSI resolution

Student group		Forced choice		Qualitative	
		Pre MD	Post MD	Pre MD	Post MD
No MRSIP	*N*	50		48	
		4.0	4.0	2.0	2.0
MRSIP no field trip	*N*	12		10	
		3.0	3.5	1.5	2.0
MRSIP with field trip	*N*	23		21	
		4.0	4.0	2.0 †	2.0 †

†Significant pre to post difference within groups

4.3 Role of Science and Non-Science Factors for SSI Resolution

Kruskal–Wallis *H* tests demonstrated no significant differences existed across the three student groups' pre-MRSIP scores measuring their forced choice and qualitative views about the extent that science should play the only role in resolving SSI such as pallid sturgeon decline ($p > 0.05$, Table 6). No significant changes occurred from before to after the MRSIP regarding any of the student groups' scores measuring their forced choice views about this NOS dimension ($p > 0.05$). The MRSIP non-participating and MRSIP after-school participating students' pre- to post-qualitative responses regarding the extent that science, in comparison to other factors, should play the only role in resolving environmental SSI remained unchanged ($p > 0.05$). However, students completing all aspects of the MRSIP demonstrated a significant and moderately large gain in their scores measuring these qualitative NOS views ($p = 0.02$, $Z = -2.4$, $r = 0.37$).

The proportion of students providing responses demonstrating uninformed or nonsensical views of the extent that science should play the only role in resolving environmental problems reduced between 19 and 24% across the MRSIP non-participants and participants from before to after the MRSIP (Fig. 9). Students' providing such views about this NOS dimension included Mary, Brianna, Edith, and Michael, all full MRSIP participants, who responded prior to beginning the MRSIP program "I don't know." Joanne, David, and Asha, respectively a MRSIP non-participant and two MRSIP after-school participants, similarly responded that they did not know and were unsure whether science should play the only role in resolving environmental SSI.

From before to after the MRSIP, the percentage of students providing stereotypical views that indicate science plays the only role in contentious environmental issue resolution increased, respectively, from 8 to 19%, 20 to 30%, and 5 to 14% across the MRSIP non-, after-school, and full participating groups. Anna, a MRSIP non participant, as will be addressed later, generically indicated on pre-MRSIP measures that other factors beyond science might be considered for environmental issue resolution. However, her response provided on post-MRSIP measures were quite stereotypical in that she thinks that science, and not peoples' opinions and feelings, should be the only source of contentious environmental issue resolution.

> I think science should be the only thing that should be used to fix all the problems. It's because science is a fact and not an opinion. Since an opinion is how it feels, it could be not true to everyone. So, science should be the only thing that should be used to fix all the problems. *Anna MRSIP non participant, post-score "1"*

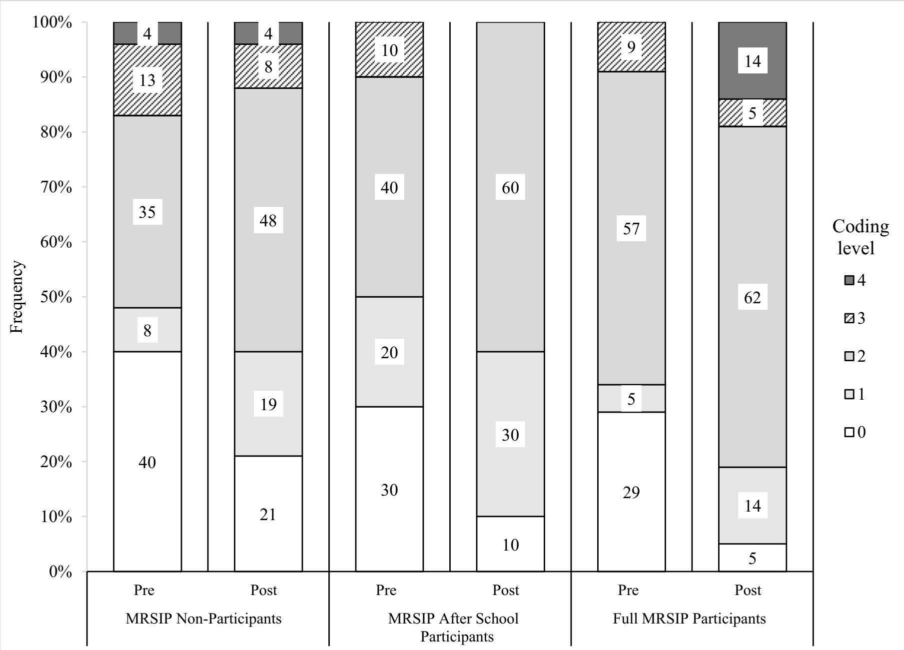


Fig. 9 Distributions of MRSIP non-, after-school, and fully participating students' pre-and post-MRSIP responses about the extent science should play the sole role in environmental issue resolution. Note, percentages rounded to whole number and 0 = nonsensical/ uninformed, 1 = stereotypical, 2 = transitional, 3 = implicitly transcending, 4 = explicitly transcending

David, a MRSIP after-school participant who's previously discussed pre-MRSIP response was rated unaware, provided post-MRSIP sentiments that indicate science and scientific experiments should play the only role for environmental issue resolution.

> Science should be the only thing because experiments are really helpful like the other times. David *MRSIP after-school participant, post-score "1"*

Gerry, prior to beginning and completing the full MRSIP program, also responded that science and scientific evidence should play the sole role in contentious environmental issue resolution. More specifically, Gerry's comment below appears to place the entire onus on scientists to ensure that the Missouri River continues flowing.

> I think they [scientists and science] should. Because if they don't fix this the Missouri River may have a day with no water in it. *Gerry MRSIP full participant, pre-score "1"*

The percentage of MRSIP non-participants' responses that were rated as transitional, where they tacitly and generically acknowledge that factors other than science play a role in resolving environmental problems, respectively increased from 35 to 48% from before to after the MRSIP. Across that same time period, the proportion of MRSIP after-school and full participants providing such responses, respectively, increased from 40 to 60% and 57 to 62%. Anna, a MRSIP non-participant, who's stereotypical post-MRSIP response was previously addressed, provided a pre-MRSIP response appearing below that was coded as transitional because it tacitly indicated non-scientists may have knowledge that can contribute to environmental issue resolution.

I think science could be used for these problems. It's because normal people know about fish as much as scientists do. *Anna MRSIP non participant, pre-score "2"*

Mark provided similar views to Anna's prior to completing the full MRSIP.

I think science should not be the only thing because public opinion is very important. Mark *MRSIP full participant, pre-score "2"*

Joanne, a MRSIP non-participant, Asha a MRSIP after-school participant, and Edith, a MRSIP full participant, as previously discussed were unaware of the role that science should play in resolving environmental problems. However, they all responded similarly on post-MRSIP measures that non-scientists could contribute to the resolution of those issues.

No!! It [science] can help, but other people need to help too! Joanne *MRSIP non participant, post-score "2"*
Science shouldn't [be the only thing to fix environmental problems] because we are all a big family and we can work together to figure things out. Asha *MRSIP after-school participant, post-score "2"*
They [scientists and science] shouldn't [have the only say regarding environmental issues resolution] because if someone has a different idea that could work. That's why people should help them. Edith *MRSIP full participant, post-score "2"*

MRSIP non-participating students providing implicitly transcending views that recognize, but narrowly describe, other factors and/or stakeholders beyond science that should play a role in environmental issue resolution decreased from 13 to 8%. The percentage of MRSIP after-school and full participating students providing similar views, respectively, fell from 10 to 0% and from 9 to 5% from before to after the MRSIP. Wendy, a MRSIP non participant, provided responses on both pre- and post-MRSIP measures that advocate that science should not play the sole role in resolving environmental issues. For example, Wendy's first response in Fig. 10 below tacitly indicates indigenous knowledge holds some value for resolving environmental issues.
Wendy provided almost identical sentiments on the post-MRSIP measures.

[Scientists] shouldn't [have the only say]. People that have lived there have seen how it changed. They were there. *Wendy, MRSIP non participant, post-score "3"*

Prior to beginning and completing the entire MRSIP, Regina indicated that resolving environmental issues entails using mathematics to advance scientific work. However, she also tacitly indicates in the response below that political processes should also play a role in resolving these issues.

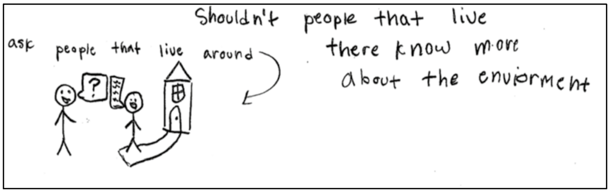


Fig. 10 Illustration provided by Wendy, *MRSIP non participant, pre score "3"*

> [Scientists] shouldn't [have the only say] because you can use math to calculate populations of fish and how that has changed, and also create a ballot to let the public decide what they think is right. The scientist's opinion might not be the best opinion. *Regina MRSIP full participant, pre-score "3"*

Gerry, who's pre-MRSIP stereotypical views regarding this NOS dimension were previously addressed, indicated after completing the entire MRSIP that scientists and science should not be the sole determinant of environmental issues. Furthermore, Gerry implies that those seeking outdoor recreation and sporting opportunities should also be considered.

> I think they [scientists and science] shouldn't because when someone was fishing pallid sturgeon to eat, that is not good. *Gerry MRSIP full participant, post-score "3"*

The percentage of MRSIP non-participating students providing explicitly transcending views, where they specify factors and/or stakeholders beyond science that are important for environmental issue resolution, remained stable at 4% from before to after the MRSIP. None of the MRSIP after-school students provided such views before or after participating in the MRSIP. Across the same time period, the percentage of MRSIP full participants providing explicitly transcending views regarding the role that factors beyond science play in resolving environmental problems increased from 0 to 14%. Again, Mark's views prior to the MRSIP were considered transitional in that he generally felt public opinion should play a role in environmental issue resolution. However, after completing the entire MRSIP, Mark explicitly addressed that stakeholder perspectives must be considered when resolving environmental issues. More specifically, Mark appeared to draw from his experiences on the MRSIP when stating that constructing a chute to protect pallid sturgeon will disturb farmland. Mark then considered the farmers' perspective as evidenced by his response provided below.

> The chute will not make the farmers too happy. So, science shouldn't be the only thing used to help the pallid sturgeon. *Mark MRSIP full participant, post-score "4"*

Regina, who's pre-MRSIP implicitly transcending views regarding this NOS dimension are previously addressed, explicitly indicated in her response after completing the full MRSIP that environmental issues resolution required utilizing multiple disciplines within science, technology, engineering, the arts, and mathematics.

> It [scientists and science] shouldn't because it also requires math to calculate numbers, art to design the new plan and architecture to create models. *Regina MRSIP full participant, post-score "4"*

5 Discussion and Implications

This investigation builds upon previous efforts to identify instructional approaches that promote accurate NOS views among young learners. However, our study takes a novel step by investigating how place-based SSI instruction that utilizes inquiry and argumentation strategies in after-school and field settings can promote more sophisticated and authentic NOS views among young learners. In summary, our findings demonstrate the following:

- MRSIP non-participants did not significantly improve their NOS views.
- Students completing only the after-school MRSIP sessions developed significantly more informed forced-choice responses advocating that scientists investigated pallid sturgeon through many different methodological approaches beyond using a step-by-step experiment.
- Students completing all MRSIP sessions (after school and field trip) developed significantly more informed and contextualized views regarding the extent scientists' simultaneous observations and claims can disagree. Those students also became significantly more aware of the non-scientific and sociocultural considerations (e.g., local residents' perspectives, economic concerns, and property rights) that should, in addition to science, play a role in resolving contentious environmental issues.

Some may conclude that these findings are not entirely surprising given that the MRSIP program activities focused explicitly on the NOS themes learned by the MRSIP students (see Table 1). However, the findings from this study do not support the interpretation that all students' NOS views will be positively impacted by increasing amounts of explicit and contextualized NOS experiences. Several students' NOS responses appeared to become less accurate and robust after completing the MRSIP. This was particularly the case for some MRSIP after-school participants, rather than for the full MRSIP participants. Perhaps for these students, the after-school MRSIP alone did not provide sufficiently rigorous explicit and reflective NOS experiences to challenge the stereotypical NOS views that they may have encountered through their classroom learning and everyday lives. The results of this investigation highlight the potential value of informal learning experiences for promoting younger students' NOS understanding. Such approaches may serve to augment elementary classroom instruction where teachers often do not deeply address science, let alone NOS, for a bevy of reasons to include time constraints, pressure to cover non-scientific curriculum (e.g., literacy), and deficiencies in specialized scientific knowledge (Banilower et al., 2013; Blank, 2013; Brunner & Abd-El-Kahlick, 2020; Herman et al., 2019; Rogers et al., 2020).

Our study adds to the limited scholarship attempting to address the range of sophistication to which elementary students can learn NOS when provided the appropriate learning contexts (Abd-El-Khalick, 2012; Akerson et al., 2011; Leden & Hansson, 2019). Abd-El-Khalick (2012) presents more general and declarative NOS learning targets at the elementary level and provides examples, including that science is supported by evidence such as observations of the natural world. However, Abd-El-Khalick (2012) clarifies that domain-general and domain-specific NOS approaches are complimentary and synergistic, and cites other scholarship (e.g., Wong et al., 2008) to illustrate how using context-rich explorations can facilitate nuanced NOS understandings. Erduran and Dagher (2014) use a family resemblance approach and appear to link NOS learning targets to grade-specific science contexts. For instance, at the primary grades, students can learn about the social aspects of science (e.g., how scientists establish findings and how different issues affect societal decisions) through an environmental context. Leden and Hansson (2019) investigated six teachers' (grades

1–9) suggestions and rationales regarding a learning progression for NOS instruction. Some NOS themes were considered to be readily accessible by young learners, such as the empirical and creative aspects of science, particularly because those themes could be linked to hands-on activities. However, the sociocultural aspects of science were identified by the teachers as inherently abstract and, similar to Akerson et al. (2011), recommended that in most cases should be taught in later elementary grades. In summary, Leden and Hansson (2019) postulate that appropriate planned and spontaneous pedagogical approaches, contexts, and experiences can make complex NOS ideas more accessible for young learners (see Clough, 2006; Herman et al., 2013a, b; Erduran & Dagher, 2014; for more discussion regarding these approaches).

The findings from this investigation empirically substantiate guidance from Leden and Hansson's and others' work about elementary NOS teaching and learning through demonstrating that the fourth-grade students who experienced the highly contextualized MRSIP were able to develop more nuanced and accurate conceptualizations about abstract NOS ideas. For instance, the MRSIP participants learned that argumentation and disagreement is a required aspect of observing and establishing factual claims about the natural world. Students who completed all aspects of the MRSIP also cited more complex sociocultural dimensions (e.g., indigenous perspectives, land use issues) in their responses regarding Missouri River SSI resolution. Leden and Hansson (2019) found that the former NOS aspect was identified by teachers to be feasibly implementable as early as grades 1–3. Those same teachers indicated also that the latter NOS ideas should be reserved for grades 4 and later. Thus, the students investigated here demonstrated NOS learning capabilities commensurate with learning progression considerations put forth by Leden and Hansson (2019) and others (e.g., Erduran & Dagher, 2014).

Beyond providing more informed responses regarding general NOS aspects, many of the students drew from their MRSIP experiences to contextualize those responses. For instance, some referred to the actual methods (e.g., tracking) used by pallid sturgeon biologists on the Missouri River. Other students cited authentic local social, economic, and cultural concerns that accompany Missouri River SSI. We attribute the students' success with developing such nuanced and contextualized NOS views to the planned and spontaneous pedagogical support they received alongside their firsthand experiences with place-based SSI that highlighted NOS ideas and made them more concrete and accessible. However, this investigation only assessed students' perspectives regarding a limited number NOS dimensions. Substantial empirical work is still needed to fully determine how and to what extent young learners of varying ages can conceptualize a variety of NOS aspects through diverse formal and informal learning experiences. Furthermore, NOS must be given a greater priority than what is present in current standards such as the NGSS, and presented in a manner that guides teachers and researchers to implement it in developmentally and contextually appropriate ways across grades K–12 (McComas & Nouri, 2016).

5.1 Limitations

Despite our positive findings regarding how place-based SSI instruction can promote young learners' NOS conceptions, a few limitations of this study are noted here to guide future-related scholarship. Most notably, due to an inability to manipulate the students' classroom learning experiences and require their participation in the MRSIP, we were unable to implement a true experimental design where the participants were randomly assigned to intervention and control groups, and the same science and NOS topics were addressed under different conditions (e.g., in classrooms versus informal field settings). Future studies, if possible, should attempt to implement such robust research designs. Instead, this investigation utilized two intervention groups that experienced the MRSIP curriculum to varying degrees and a comparison group consisting of the MRSIP participants' classroom peers. The students who enrolled into the MRSIP intervention did so through non-random voluntary self-selection. This is a typical scenario for non-compulsory and free choice learning opportunities that, combined with the unique and non-replicable nature of the MRSIP, leads to a lack of generalizability of this investigation's results.

The non-random allocation of participants across the three groups resulted in unequal sample sizes and likely some variation of pre-existing characteristics (e.g., cognitive and affective) across those groups. For example, participants completing all MRSIP components had significantly, yet modestly, higher pre-scores measuring their qualitatively expressed views about how scientists research pallid sturgeon than their peers who did not enroll in the MRSIP. That is, prior to the MRISP, those electing to participate in all aspects of that program better understood than their non-participating classroom peers that scientists conduct their work in diverse settings (e.g., field studies) through various methods that do not necessarily follow a rigid step-by-step procedure. It is possible that these students' interest in and self-selection into the MRSIP was motivated by their better understanding of this NOS aspect. Some have asserted that learning about and understanding NOS can help students understand that science is not a stepwise and sanitized process, and thus enhance their interest and engagement in science (McComas & Clough, 2020). This is an area that needs further investigation—particularly in the interest of understanding how to motivate students to take on science learning opportunities beyond those presented through their classroom curriculum, which as noted before can be quite sparse.

While working with the qualitative data, we found some students' drawn responses to be somewhat difficult to code. This is to be expected from younger students when eliciting their views about complex topics through drawings as Bland (2018) citing Horn (1998, p. 227) notes “not all visual language is instantaneously understandable.” However, Bland (2018, see also Bland, 2012; Barraza, 1999; Walker, 2007) also notes that drawings have increasingly been recognized as a valid data source for school improvement and education research efforts because they can facilitate students to relinquish concepts, particularly when they may struggle to do so through other data collection approaches or because of language difficulties. To ensure student drawings serve as a valid data source, Bland (2012, 2018) advocates that research using such data sources must ensure credibility through methodological design and analytical approaches. For instance, triangulating measures (e.g., interviews and written and forced choice survey responses), analytical coding rubrics, and independent coding can facilitate researchers' ability to reliably assess and compare the content present in illustrative data. Unfortunately, given the timeline of this study and access granted to the students, we were unable to conduct interviews to better understand the students' qualitative responses. However, our study design and methods entailed several aspects that attempted to mitigate the issue of some students' abstruse drawings, and the aforementioned issue of participant self-selection. First, the inclusion of a dedicated comparison group, a group experiencing most of the MRSIP, and a group experiencing all aspects of the MRSIP allowed comparing data sources across these groups. This facilitated much more insight of the impact of MRSIP than if we had implemented a simple pre-post design only involving an intervention group. Notably, the majority of research where interventions are used to improve young learners' NOS conceptions, including those reviewed in this manuscript, consist of simple pre-post designs. Second, our survey measures enabled triangulation of the students' forced choice, written, and drawn responses regarding NOS to improve accuracy of qualitative coding. Third, our rigorous and iterative semi-grounded rubric development and coding procedures occurring through multiple rounds of independent analysis and cross-comparison of data sources sought to categorize the students' written and drawn NOS views efficaciously and transparently. Fourth, we generously provide transparent exemplars in this manuscript and in the Appendix to help demonstrate how the students' responses varied. While these mitigating efforts certainly augmented the robustness of this study, future research efforts should attempt to utilize true randomized control and intervention groups and conduct interviews in order to further elucidate students' NOS views and their relationship to various pedagogical practices.

5.2 Pedagogical Implications

Many scholars have written about the paltry attention typically paid to NOS instruction at all levels of schooling, particularly at the elementary levels where the focus on science is already often scant (Akerson & Abd-El-Khalick, 2005; Akerson et al, 2011). In this investigation, we ascertained that the NOS instruction occurring in the participating students' classrooms was fairly typical in that it was non-existent; and there seemed to be a "dosing" effect where students completing all aspects of the MRSIP improved their NOS views substantially in comparison to their peers who completed none or only the after school components of that program. We attribute the students' NOS learning to the characteristics of the MRSIP program, which again purposefully used research-based pedagogical strategies to promote learner engagement and set the context for deeply addressing SSI and NOS (Herman et al., 2013a, b).

The utilization of place-based contexts to address the complex aspects of SSI is becoming more pervasive in the science education community (Herman et al., 2021). These approaches promote ecological and sociocultural awareness and sustainability through leveraging students' sense of place and attachment to real people and the environment impacted by SSI. The situated, experiential, and contextual features of the MRSIP provided the students a concrete and relatable SSI context that that facilitated their NOS engagement and connections to the local environment and community. More specifically, early in the MRSIP, students learned how human-induced changes to the Missouri River caused pallid sturgeon declines, how scientists research pallid sturgeon and implement pallid sturgeon recovery efforts (e.g., interception rearing complexes and river chutes near where the students lived), and the social implications accompanying those efforts. Furthermore, in the first lesson, the students learned how to frame their thinking and arguments through the Claims, Evidence, and Reasoning framework (CER), which underpinned subsequent instruction. However, unlike many applications of the CER framework, we taught that evidence for an argument regarding SSI can be scientific as well as economic, historical, and sociocultural in nature. We also differentiated the drawbacks and merits of these various forms of evidence. Notably, many students gravitated toward the CER framework, used it enthusiastically; and the students and teachers expressed that it aligned with their classroom persuasive writing activities used in literacy instruction. Innovative applications of the CER framework and other argumentation approaches to create scaffolds to NOS have been reported elsewhere (Khishfe, 2014; Rogers et al., 2020), and variations of these approaches should be further explored in diverse learning settings.

Following learning about how to frame arguments using the CER framework, multiple planned and spontaneous activities occurred throughout the MRSIP to facilitate students' engagement and understanding of the Missouri River SSI. For instance, during the after-school component of the MRSIP the students participated in stream table activities that simulated how human activities impacted the Missouri River and watched documentary footage about pallid sturgeon adaptations and habitat, and scientists' efforts to manage declining pallid sturgeon populations. On the field trip to the Missouri River, the students experienced a guided boat ride where they observed and learned about interception rearing complexes and river chutes and interacted with fisheries biologists and learned about their research and management of pallid sturgeon. The students then drew from what they learned to engage in a debate, using the CER argumentation framework, to select a management plan for pallid sturgeon recovery.

We reiterate these activities to point out that they were synergistic, built upon one another, and provided opportunities for highly engaging scaffolding questions and discussions to include those focused on aspects of the SSI, including the NOS. The use of more complex pedagogical approaches such as these to scaffold across contexts and engage students in deeper NOS discussions has been documented throughout the literature (Allchin, et al., 2014; Herman, 2018; Clough, 2006; Leden & Hansson, 2019). For instance, Allchin et al., (2014, p. 467) emphasize that:

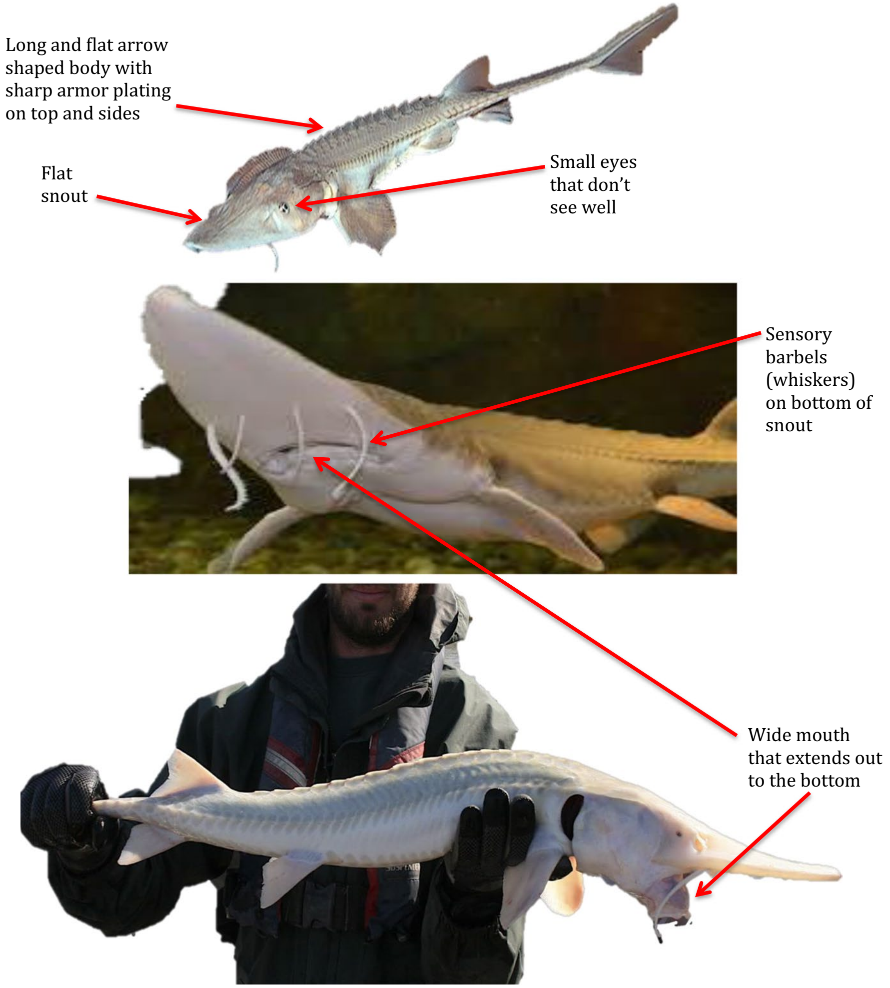
> In summary, contemporary cases (including SSIs as an important subset) thus seem suitable for introducing some aspects of NOS and can contribute to student appreciation of the *importance of* understanding NOS. The relevance and familiarity of the cases make the abstract more tangible. … In addition, they can apply their NOS knowledge in debates about authentic SSIs and practice the skills of competent citizens in a "rehearsal" environment.

However, also documented in the literature is the disappointing reality that few teachers are well prepared and able to carry out such advanced NOS instruction that facilitates students' proficient socioscientific engagement as citizens (Backhus & Thompson, 2006; Herman, 2013a). If the science education field seriously considers NOS an important component of a functional scientific literacy, then standards, preservice teacher education, and teacher professional development efforts must reflect that through dedicated and sustained focus on NOS and NOS pedagogy. Otherwise, the field may never overcome trends identified decades ago that teachers often perceive NOS as unworthy of being emphasized as a cognitive objective and detracting from content instruction; and thus, they refrain from accurately and effectively teaching NOS (Abd-El-Khalick et al., 1998; Clough, 2006).

Appendix

MISSOURI RIVER ASSESSMENT PART 1

Below are pictures of a kind of fish called a pallid sturgeon. Please use these pictures when answering the questions on this test.



Your name:___________________ Your grade:_____ Teacher's name:______________________

Are you in Missouri River After School Program? Circle one: Yes No

Answer the following questions the best you can. Please use drawings if you think they will help you explain your answers. Please ask your teacher if you have any questions about this test.

1. **Using the pictures of pallid sturgeon, make a claim based on two body parts** about the kind of habitat they like and survive best in. **Use evidence from the pictures** to support your claim.

2. **Draw and describe the habitat sturgeon** would survive best in based on your answer.

3. **Based on your answers above, draw and describe** ways that changes to the river habitat may cause pallid sturgeon populations to decline. **Use evidence from the pictures to support your claim.**

4. Mr. Oliver and Ms. Jenna are scientists that study fish. Please answer how you think Mr. Oliver and Ms. Jenna **should investigate** pallid sturgeon if they want to get good evidence and make truthful claims about them. **Fill in the circles of ALL of the statements you think are true:**

- ○ Their investigation **must** use a step-by-step experiment.
- ○ They **should only** investigate pallid sturgeon in the laboratory.
- ○ Most investigations of pallid sturgeon **should** happen in their natural habitat.
- ○ A step-by-step experiment isn't always the best. They **must create and use** many different methods for their investigations.

5. **Draw and explain** how you think scientists like Mr. Oliver and Ms. Jenna **should investigate** pallid sturgeon. Please provide examples to help your answer.

6. **At the same time**, Mr. Oliver and Ms. Jenna observe and make claims about how and why a pallid sturgeon uses its barbels. **Fill in the circles of ALL of the statements you think are true about scientists:**

○ They **should never** disagree when they observe the same things in nature.
○ They **can** disagree because they can make different observations of the same things in nature.
○ Their thoughts about the same things they observed in nature **should always be the same and agree**.
○ When observing the same things in nature it is **normal** for them to have different thoughts and disagree.

7. **Explain** if you think scientists like Mr. Oliver and Ms. Jenna **should or shouldn't** disagree when observing and making claims about nature. Please provide examples and drawings if it helps your answer.

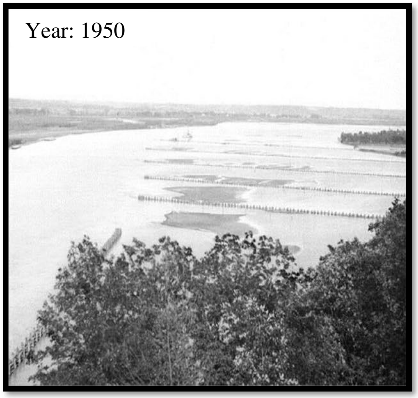
8. Were there any questions you did not understand or that you were unable to answer completely?

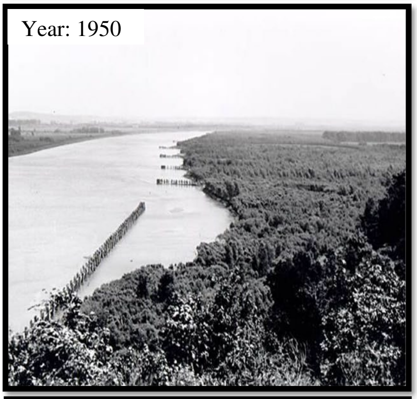
Yes No

If yes, please explain which questions and what you did not understand or what made it hard for you to finish them.

MISSOURI RIVER ASSESSMENT PART 2

Humans have made changes to the Missouri River that has caused pallid sturgeon populations to decline over time from 1925 to 2015. The pictures below show the changes to the Missouri River. Please use these pictures to answer the questions on Test 2.





Your name:___________________ Your grade:_____ Teacher's name:______________________

Are you in Missouri River After School Program? Circle one: Yes No

Answer the following questions the best you can. Please use drawings if you think they will help you explain your answers. Please ask your teacher if you have any questions about this test.

1. What changes do you notice in the pictures of the Missouri River from 1925 to 2015?

2. Explain why you think the changes you noticed have caused sturgeon populations to decline. Make sure to use evidence to support your claims.

3. Based on your answers about the changes to the river, describe a plan that would help fix the problem of declining sturgeon populations. Explain why your plan would fix the problem and the kinds of evidence you are using.

4. Describe the good and bad parts of your plan including why other people may or may not like it.

5. Mr. Oliver and Ms. Jenna are scientists who were talking about how environmental problems like sturgeon populations declining should be fixed. **Fill in the circles of ALL of the statements you think are true:**

- ○ **Only** scientific evidence should be used to fix environmental problems like this.
- ○ Scientists **should not** have the only say about how to solve environmental problems like this**.**
- ○ Science **will** solve all of our environmental problems including this one.
- ○ **Other things** besides scientific evidence (like public opinion) should be used when fixing environmental problems like this.
- ○ **Science by itself** cannot solve all of our environmental problems including this one.

6. **Please explain** if you think science **should or shouldn't** be the only thing used to solve environmental problems like pallid sturgeon population declines. Please provide examples and drawings if it helps your answer.

7. Consider environmental problems like sturgeon populations declining because of changes to the Missouri River. **Fill in the circles of ALL of the statements that best describe how you feel:**

○ I don't care if **nature** (like pallid sturgeon and rivers) is harmed because of what people do.
○ I only feel a little bit bad for **nature** (like pallid sturgeon and rivers) that is harmed because of what people do.
○ I feel very sorry and bad for **nature** (like pallid sturgeon and rivers) that is harmed because of what people do.
○ I believe we have to take care of **nature (**for example: giving money to fix pallid sturgeon habitat) that is harmed because of what people do.
○ I feel like we shouldn't have to take care of **nature (**for example: giving money to fix pallid sturgeon habitat) that is harmed because of what people do.

8. **Explain using examples** if you feel sorry for and think we should take care of nature that is harmed because of what people do. Please provide examples and drawings if it helps your answer.

9. Were there any questions you did not understand or that you were unable to answer completely?

Yes No

If yes, please explain which questions (number and letter, for example 1a) and what you did not understand or what made it hard for you to finish them.

Declarations

Conflict of Interest The authors declare that they have no conflict of interest.

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